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The Philadelphia
Correspondence Schools
of
Foundry Practice

Dr. Edward Kirk's System
of Foundry Practice

METALLURGY
OF FOUNDRY IRONS
AND FOUNDRY
PRACTICE

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IRON

CHAPTER I.

In the study of iron, the first aim of the student should be to learn the source from which it is obtained, method of production, and various grades and qualities of iron.

The source of supply is from iron ore, of which there is an abundant supply in this country, as almost every state in the union has iron ore deposits to a greater or less extent; and the deposits that have been opened up and are being worked, have been estimated to be sufficient to supply our wants for a hundred years at the present rate of consumption of iron. Our coal supply for smelting is also unlimited, so there may be no fear of scarcity of iron or that the present high price of pig-iron (fifty dollars per ton) will be maintained for any great length of time. During our Civil War, pig-iron sold as high as seventy-five dollars per ton, and several times since that date has reached abnormally high prices, but after each of these high-priced periods it declined to its normal price, and in some cases even below, and sold as low as eight to ten dollars per ton at the furnace. With the abundance of ore, fuel and blast furnace facilities in this country, the present high prices cannot possibly be maintained, after the thousands of tons being shot away in the present trench warfare has ceased.

Iron ores are designated as red hematite, brown hematite, black band, magnetic, high manganese, high silicon, etc. Ores are also designated by the location in which they are found such as, Bog Ores, Lake Superior, Cornwall, Iron Mountain, etc. These terms or names indicate to a large extent the quality of iron that may be obtained from them and are of more interest to the furnacemen than the foundrymen.

The fuels used in smelting ores are charcoal, coke and anthracite coal. The ore is smelted in blast furnaces, in direct contact with their fuels, and they have a direct influence upon the characteristics of the iron, and frequently give to it certain characteristics not found in the ore.

Pig Irons

Foundry Iron.

The term foundry iron is used to indicate that a pig-iron is a soft machinable iron, possessing fluidity and other desirable qualities for castings. This term covers a large variety of iron and does not always indicate that the iron is suitable for the line of work to be cast, as a stove plate iron is too open and porous and does not possess the strength required in heavy castings, and an iron suitable for heavy castings would run too hard for stove plate, and it is the practice in ordering iron to order by analysis or to indicate the kind of castings the iron is to be melted for, and leave it to the iron broker or furnaceman to ship a suitable iron.

Besides the soft iron, commonly designated foundry iron, there are a large number of special foundry pig, such as car wheel pig, bessemer pig, malleable pig, high silicon pig, high manganese pig, high phosphorous pig, etc. These irons are designed for castings requiring special characteristics such as hardness, softness, chilling properties, strength, annealing properties, etc., and are melted alone or in mixtures with other irons, to give these characteristics to the castings in a modified form or to give fluidity or flowing properties to a sluggish iron, and cause it to run up sharp in the casting.

Cold Blast Charcoal Pig.

In the early days of the iron industry in this country, all pig-iron cast was cold blast charcoal iron, that is, the ore from which it was obtained was smelted with charcoal fuel, and a blast of the normal temperature of the atmosphere.

The blast furnaces in which this iron was smelted were all small ones. A furnace of twelve ton capacity being considered a large one, and the small ones four to eight tons per day, and this is still the average size of charcoal smelting furnaces. With the disappearance of the forest from which wood for charcoal making was obtained for smelting, these furnaces have also disappeared to a greater or less extent and the output of this iron at

the present time is almost entirely limited to a few of the Southern States and the Lake Superior Iron ore region. The output of this iron is very limited and so high in price that it can only be used for special castings requiring great strength or a deep chill.

This iron is the strongest of all the foundry irons and has the most marked tendency for chill when suddenly solidified against a cold chill. It was the only iron used for malleable iron and car wheels for many years, but at the present time the entire output of this iron in a year in this country is not sufficient to supply these foundries for one day, and only a few of the smaller malleable iron and car wheel plants favorably located continue to use it exclusively. Others only use about 10 per cent. to tone up their mixture of other irons, while others have been compelled to abandon its use entirely and use coke iron with steel scrap as a strengthener and chill giver.

This iron is so strong that it is cast in pig of only about two-thirds the width of those of coke iron, and the pigs are notched on both sides to facilitate breaking them for charging and melting. All the iron cannon used before the introduction of steel cannon were cast with this iron, and it was frequently termed gun metal.

This iron, at the present time, is principally used for chilled rolls alone and in mixtures with coke iron. Outside of the Lake Superior iron region it is principally graded by fracture indications.

No. 1 is a high Silicon, low sulphur iron, with a large crystalline structure in fracture and runs soft in castings of not very light sections.

No. 2 shows a smaller crystalline structure in fracture and frequently a chill of one-eighth of an inch when cast against an iron chill.

No. 3 has a fracture similar to that of a forged coke iron, and shows a one-fourth inch chill when cast against a chill.

No. 4 gives a chill of three-eighths to three-fourths of an inch in depth.

No. 5. The fracture is strongly mottled and gives a chill of three-fourths to one and a half inches.

No. 6 is a white iron, practically all the carbon being in a combined state.

A mixture of these grades gives a chill of almost any desired depth when cast against a chill, and a very hard or strong iron when not cast against a chill, and is regarded as the very best metal for rolls of any size, for rolling metal, either hot or cold.

One of the tricks of foundrymen after the introduction of anthracite and coke irons, which were regarded at that time as inferior, was to keep a pile of charcoal pig in the yard, to show the customer the quality of iron to be placed in his casting. When a customer desired a very strong iron in his casting, he was taken into the foundry yard and a pig of this iron broken after numerous blows with a heavy sledge. This test generally satisfied the customer, who believed he was getting an extra quality of iron, while the pig broken was probably the only one that went into many tons of his castings, the castings being made from the cheaper grades of pig. This trick is still resorted to by some small founders to show the strength of their iron, and also that they do not use all scrap for first-class castings.

Hot Blast Charcoal Pig.

Hot blast charcoal pig is an iron smelted with charcoal fuel and a hot blast. This iron is smelted in furnaces of about the same design and size as the cold blast charcoal furnaces, the only difference being, that the blast is heated before being forced into the furnace. The heating of the blast is found to have a softening effect upon the iron, and greatly reduce its chilling tendency, when sand or chilled cast, and make it the very best iron for castings of very light section, as the number one and two grades run very fluid and soft, the lower grades have a tendency to chill. A mixture of them with a white iron produces a very satisfactory chill, although not considered to be so hard or possess wearing properties equal to the cold blast iron.

Hot blast charcoal iron at one time was the leading iron for light soft castings, and there was a number of famous brands of this iron, among them the hanging rock brand, made in the Ohio Hanging Rock District, on the Ohio River, above Cincinnati. This iron commanded a good price and even after the second growth timber in this district became exhausted for charcoal making, charcoal was hauled many miles from Virginia by six-ox team and the furnaces kept in blast. But this supply too became exhausted and the furnaces were forced out of blast.

This iron, like the other famous brands, has now almost entirely disappeared from the market and our supply of hot blast charcoal iron at the present time comes from isolated dis-

tracts where wood for charcoal making is plentiful. The supply of this iron is very limited. But as the present generation of foundrymen know but little about the superior qualities of this iron as a foundry iron, the demand for it is also limited. Hot blast charcoal is generally considered the very best iron for soft, strong castings. Cold blast charcoal iron is the best strong chilling iron. Next to these for foundry work is the anthracite and coke irons, which differ in their characteristics to some extent, dependent upon the per cent of sulphur and other impurities the smelting fuel may contain. But in all cases, the selection of the ore has more to do with the quality of the iron, than the smelting fuel.

Iron ores are smelted in blast furnaces and the iron cast direct from the furnace into bars, which are designated pig-iron. This iron is the crudest form of commercial iron we have to deal with, for it has not been refined in the process of smelting but merely separated or extracted from its ore, and contains many of the impurities of the ore and may also have taken up impurities from the smelting fuel. The presence of the more volatile of these impurities in the pig, is no great detriment to the iron when manufactured into steel or wrought iron, for they are burned out in the process of making these metals, but in foundry irons they are of great importance, for they give to the iron the various characteristics that fit it for light and heavy castings, soft or hard castings, chilled castings, strong castings, etc. And the effect of these impurities or metalloids upon the iron, should be carefully studied by the founder, that by increasing or decreasing the various metalloids in his mixture, he may be able to produce an iron of a desired quality for his casting.

These impurities in pig-iron are termed elements or metalloids, and by increasing a softening metalloid in a mixture, a softer iron is obtained and by decreasing it a harder iron is obtained. The same effect is produced by a fluidity giver, or strengthener and a more fluid or stronger iron is obtained, by increasing these metalloids in a mixture.

A desired per cent of any metalloid in a mixture may be obtained by using pig containing a higher or lower per cent of the metalloid or by placing an increased or decreased per cent of the same pig, in the mixture.

Warm Blast Charcoal Pig.

This iron is smelted principally in the Lake Superior iron ore districts with by-product charcoal and a blast heated to from

500 to 900 deg. Fah. This iron is graded by analysis and presents fourteen different grades which are designated as follows: A—Scotch, B—Scotch, C—Scotch, Low No. 1, High No. 1, Low No. 2, High No. 2, Low No. 3, High No. 3, Low No. 4 and High No. 4, Low No. 5 and High No. 5 and No. 6.

The maximum silicon in the A Scotch is 2.62 and in the No. 6 .05. The grading is made by the silicon from the A Scotch, which is a very soft iron, down to the No. 6, which is a white iron. The other metalloids in this iron are Phosphorus, .15-.23, Manganese .30-.70. Sulphur, trace to .018.

The fine grading of this iron is probably more theoretical than practical owing to the enormous amount of labor and expense of such accurate grading and the iron generally shipped to suit the work for which it is designed.

This iron is used in this section of the country for soft and general run of castings, and is also used in this and other sections for car wheel, chilled rolls and other close or hard castings. But it does not appear to possess all the fine qualities of the old cold or hot blast charcoal iron, which is probably due to some essential element being extracted from the charcoal in a by-product process of making.

The softer grades of this iron are being quite extensively used for general lines of castings, by foundrymen in Northwestern Wisconsin, Michigan and Minnesota, where it can be delivered in the yard at about the same price as coke irons of the same qualities.

Some of the foundrymen did not speak very highly of this iron at my last visit to this section and stated that they preferred coke iron at the same price for soft castings.

Gun Metal Pig.

Gun metal iron was a name given to their iron by charcoal furnace men making an extra strong iron, suitable for cannon, in the days of cast iron cannon.

With the disappearance of charcoal iron and the introduction of anthracite and coke iron, charcoal gun metal disappeared and foundrymen endeavored to reproduce it from mixtures of the stronger brand or grades of anthracite and coke irons, melted together and cast into pigs to be remelted for castings.

This pig was given the name of gun metal pig, and the foundry making and using it the name of The Gun Metal

Foundry, which was designed to indicate that the foundry used a very strong iron, and made a superior grade of castings.

With a more perfect knowledge of anthracite and coke irons, it was found that equally as strong an iron or casting could be made by casting the iron direct and the expense of remelting the gun metal pig saved. This plan has been so generally adopted that there are only a very few of the gun metal foundries to be found, and these cast the greater part of their casting direct from the cupola mixture, using only the remelt gun metal pig for special large or heavy casting, required to be very strong and for which an extra charge is made for the gun metal pig.

Anthracite Pig.

With the disappearance of the forests for charcoal making and the opening of the anthracite coal mines in 1820, anthracite blast furnaces began to replace the charcoal furnaces, and to produce a pig iron designated anthracite iron or anthracite pig.

This iron was cast in shorter and thicker pigs than the charcoal pig, but weighed about the same per pig. The iron was not so strong as the charcoal iron, and the pigs did not require to be notched for breaking. It possessed the same characteristics as charcoal iron in everything except strength, but was not so deficient in strength as to render it worthless as a foundry iron.

Anthracite iron was graded by fracture indications from No. 1 to No 4, the same as charcoal iron was graded at that time. Foundrymen soon learned by mixing the different grades, to produce a casting of any desired degree of softness or hardness, having sufficient strength for the purpose for which the casting was designed, and this iron became the leading foundry iron for all that section of the country lying east of the Allegheny Mountains, including the New England States.

The anthracite furnaces were all small furnaces, although generally much larger than the charcoal furnaces. Anthracite coal was a slow smelter even with the hot blast, and the output of iron was small in proportion to the capital invested and labor required, and after the improvements made in coke making and its introduction into the eastern section, where anthracite iron was principally made, this fuel was found to be a more rapid smelter than the anthracite coal and greatly increased the output of iron from these small furnaces and was generally adopted by anthracite furnacemen as their fuel, even in the anthracite coal fields, where coal was cheap. So that anthracite iron has prac-

tically become extinct, although there are still a few furnaces using a mixed fuel of coke and coal, whose product is called anthracite iron.

Coke Pig.

Coke pig, as the name indicates, is an iron smelted with coke fuel. These furnaces are the largest of any of the blast furnaces, and are still blown with a hot blast, which together with the rapid smelting coke, smelts the ore very rapidly, and the output of pig from some of these furnaces is as high as five hundred tons in twenty-four hours.

Coke iron is the principal iron used by foundrymen at the present time and probably as high as ninety-five per cent of all the pig-iron melted in iron foundries for various lines of castings is coke pig.

This iron presents more varied characteristics than any of the pig irons, which is probably due to the rapidity with which it is smelted, and various elements or metalloids contained in the ore not being removed from the iron in the process of smelting. These elements or metalloids are very detrimental to the iron for certain lines of castings, and highly beneficial for other lines, as they impart softness, hardness, strength, chilling properties, annealing properties, etc., to the iron, and fit it for every line of castings made.

That the founder may become a practical metallurgist and mixer of iron it is necessary that he should learn the effect of the various elements upon the iron, and by manipulating the elements or metalloids found in the iron, be able to produce, from a mixture of iron, an iron of a desired quality, even when this quality is not possessed by any one of the pigs placed in the mixture.

This proposition may seem absurd to foundrymen not familiar with the metallurgy of cast iron, but these results are obtained in foundries every day, with a certainty, by practical metallurgists and by chance or knowledge of the irons gained in melting them by many founders not familiar with the chemistry of foundry iron.

The effect of the various metalloids in iron and their manipulation in mixtures will be found fully described in other parts of

this work, and should be carefully studied by the student, that he may become an expert in the manipulation of foundry irons.

Silver Grey Pig.

This was a name given to an iron that was only occasionally smelted from certain ores when the furnace was working very hot and was first called a burned iron, due to the weakness of the iron in the pig, as compared with other pig of the furnace.

It was discovered by some small founders, who were given this iron for hauling it away, that it was a very decided softener of scrap and hard iron. This discovery created a market for it, and it was given the name of Silver Grey Iron, due to its fine crystalline structure and silvery grey color of the fresh fracture. There was only one grade of this iron, although it frequently differed widely in its softening properties. This was no doubt due to the difficulty in determining a high or low softener from the crystalline structure or shade of color in the fresh fracture.

With the introduction of the chemistry of foundry irons, this iron was found to be a very high silicon iron, it was then given the name of high silicon pig or softener pig, and is now regularly smelted from ore containing a high per cent of silicon. There are large deposits of such ore in some of the Southern States, from which our principal supply of such iron is obtained and in some sections of the north it is designated Southern Softener Pig, and also Ferro-silicon Pig.

Above three per cent silicon, this iron is designated high Silicon, and according to the scale of prices, arranged by the American Foundrymen's Association, for the sale of pig by analysis, each per cent of silicon above three per cent is to be charged for extra at the rate of twenty-five cents per ton of iron, but this rule is not always strictly adhered to, as there is an abundance of this iron and furnacemen are frequently willing to sell it at any price. It can frequently be purchased in Boston and other seaports, far below the price of Northern two to three per cent silicon strong iron.

This iron is a very weak iron above three per cent silicon, and the higher the silicon the weaker it gets. As high as twelve per cent silicon pig is now being used, with only its remelt, in acid resisting castings. These castings are so weak that they have to be handled with care and packed in excelsior when shipped, to avoid breaking. This is about the highest per cent silicon iron

than can be cast. Above this point the iron rapidly loses its characteristics as iron and becomes ferro-silicon.

Southern Pig.

This iron is frequently called Southern softener and is generally understood to be a high silicon iron, but this is not always the case, for as will be seen by the analysis, in the classification and grading of pig iron, Southern irons run as low as 1.25 silicon, which does not indicate a very soft iron.

There is an impression prevailing among many Northern foundrymen that all Southern irons are high silicon weak iron; this is a mistake, for there are as hard and strong irons made in the Southern States as in the Northern States, and there are many car wheel foundries in the south using exclusively southern iron, and steel plants using southern iron exclusively.

High freight rates prevent the better grades of southern irons being shipped north and coming in competition with Northern irons. It is only the surplus of high silicon weak irons, for which there is no home market, and a demand for some in the North as a softener of Northern irons, that are shipped North. A shipment of stronger and harder irons may be made as ballast from some of the Southern seaports at any time. In ordering Southern irons to be used as a softener, it should always be designated Southern softener, or the per cent. of silicon desired in the iron stated.

Southern softener is a very similar iron to the Northern iron formerly called Silver Grey, and is sometimes designated Southern Silvery Iron.

Silvery Irons run from about three and a half to five and a half per cent of silicon. This class of iron is sometimes divided into No. 1 Silvery, which is the higher silicon, and No. 2 Silvery, the lower.

Scotch Pig.

Scotch pig is the common name by which numerous brands of pig iron imported from Scotland are known in this country.

Fifty to sixty years ago this iron was extensively used in this country as a foundry iron. It was about this time that anthracite and coke irons were rapidly replacing charcoal irons, and these irons frequently run hard in the castings of light sec-

tions and Scotch pig, which was an extremely soft rotten iron, was used as a softener and also alone for very light castings.

At that time the better brands of this iron were in demand, and sold at from one to two dollars per ton higher than American irons and were imported in large quantities. With the improvement made in the manufacture of coke and in blast furnace practice, and a more thorough knowledge of the iron ores from which the iron was smelted, our furnacemen were able to produce an equally soft iron of superior strength to that of Scotch pig; this reduced the price of Scotch pig of the better brands, to a point at which it could not be imported and sold at a profit, and only the inferior brands or off-irons were imported. These irons run so dirty that they could not be used for finished castings, to any extent, even in mixtures of American irons. About the only Scotch pig used in this country at the present time is cheap inferior brands that come into seaport towns and cities as ballast, and is purchased by foundrymen at a low price, for common castings.

American Scotch Pig.

Scotch pig was so popular among foundries that furnacemen in this country, when able, made a very soft iron having a fracture similar to that of Scotch pig and gave it the name of American Scotch Pig.

One of the furnaces that did this and still retains the name to some extent, was the Cherry Valley furnace in Ohio. This iron was smelted principally from Black Brand Ore and was equally as soft and of far greater strength than the best brand of Scotch pig and soon replaced the genuine Scotch in many localities and is still a very popular brand, although more generally known at the present time as Cherry Valley Pig.

There were many other brands of American Scotch at that time, in different sections of the country, that obtained a high reputation and are still in the market as foundry irons, but as Scotch Pig is not in demand to the extent that it was some years ago, and its high reputation has been lost, furnacemen have generally dropped the term American Scotch and the irons are known only by their local or furnace name.

Iron designated Scotch, by some furnaces, means a very soft iron containing three per cent silicon or over.

Kish In Iron.

Kish is the name given by founders to a soft flaky substance, resembling black lead, that is forced out of a very soft iron, when

in a molten state and when cooling. In casting it runs before the iron in the mold, and causes rounded edges and corners, similar to those made by blacking dusted on too heavy, and washed before the iron. In heavy castings it collects upon the surface in spots and around the edges, it adheres firmly to the castings, but is soft and easily broken off, leaving a smooth surface. Kish is only found in very soft iron, in which the softness is due to graphite or free carbon and comes from an excess of this element in the iron. Kish was very abundant in Scotch iron and was one of the objectionable features in this iron. It is not found in foundry irons used at the present time to the same extent. It was in those used some years ago and many of the younger founders have probably never heard the term Kish.

Bessemer Pig.

Standard Bessemer iron is used principally for making acid bessemer steel, the standard specifications for this iron are as follows: Silicon 1 to 2 per cent., phosphorus not over 0.10, sulphur not over 0.05.

This iron, when a little off in the above analysis, is sold as Foundry Bessemer, and when the analysis for the line of casting is right is an excellent foundry iron.

Basic Pig.

Basic pig iron means primarily a low silicon iron, the standard for this grade having silicon under 1 per cent and sulphur under .050 per cent.

This iron is used principally for steel making, and is too hard for any but specially hard castings, and is not used to any extent by grey iron founders.

Malleable Bessemer or Malleable Pig.

This pig is used for the manufacture of malleable castings, the usual specification for it is, phosphorus, not over 0.20, sulphur not over 0.05. Silicon as specified to suit the thickness of section of work to be cast, usually 0.75 to 1.25, or 1.25 to 1.75. Manganese runs as high as 2 per cent. in this iron.

This iron is designed to run white in castings to be annealed for malleables, and is not at all suitable for grey iron castings, designed to be soft.

Spiegel, Spiegel-Eisen or Mirror Iron.

This is a high manganese iron containing 10 to 40 per cent. manganese and it may be obtained at any point between these

two points, with carbon about 1.25, phosphorus 0.07, sulphur .00, silicon 0.15.

This iron is an extremely hard iron and, owing to its low carbon, is deficient in fluidity and difficult to cast in light castings. It is a steel-making iron and only occasionally used by car wheel founders for the chilling effect of its high manganese.

The present shortage in this country of manganese and its high price, which a short time ago reached five hundred and twenty-five dollars per ton, has caused users of it to cast about for a substitute, or for other sources from which to obtain it than from the manufacturers of manganese, ferro-manganese, and ores of manganese. Spiegel-Eisen was one of the first to be seized upon, and many steel founders, car wheel foundries, and others have found good, reliable Spiegel-Eisen to give as good results as an increaser of depth of chill and strengthener of cast iron as manganese or ferro-manganese, and at the present time it is being quite extensively used in mixtures of both steel and iron for castings, and its use has very materially reduced the price of both manganese and ferro-manganese.

In using this metal it is broken into small pieces and mixed with the iron in charging, or may be heated to a high temperature in the forge or other furnace and placed in the ladle of molten iron, to be melted and mixed with the iron.

Mayari Pig.

This is a comparatively new foundry iron that has only been on the market for a few years. It is smelted by The Bethlehem Steel Co., from a Cuban ore mined in the Mayari Mountains of Cuba. Two grades of the iron are made. One from Mayari ore alone, and one from a mixture of Mayari and Cuban hard ore.

This iron shows about the following analysis:

Iron 50 per cent. Mayari and 50 per cent Cuban hard ore.

Sil.	Phos.	Sul.	Man.	Chromium	Nickel
0.45	0.050	0.030	0.65	1.75	0.76

Iron 100 per cent. Mayari.

Sil.	Phos.	Sul.	Man.	Chromium	Nickel
0.85	0.950	0.022	0.90	2.90	1.52

There is also present in this iron a small percentage of vanadium and some titanium.

Mayari iron is a very hard, strong iron, and is being quite extensively used for rolls of various kinds and also for other castings requiring hardness and strength. It may be melted alone, or in mixtures with other pig or scrap, and is recommended to replace cold blast charcoal iron in mixtures. Ten per cent. in a mixture is said to increase both the tensile and transverse strength to a marked extent.

Mayari iron is not at all suitable for soft castings, and should only be used for castings designed to be hard or very close.

Other Pig Irons.

The irons just described represent the general characteristics in irons named in market quotations, but there are many other pig irons having distinct characteristics that make them suitable for certain lines of castings than other iron. The sale of these irons is generally confined to local districts and seldom named in market quotations.

When a special iron is required for a line of casting, a good plan is to consult the nearest pig iron broker, stating just what is wanted, and by so doing a suitable pig iron for any line of castings can generally be obtained; if it cannot, then resort must be had to a mixture that will give the desired iron.

Method of Casting Pig Iron

CHAPTER II.

Iron, when smelted from its ores in a blast furnace, is known as cast iron, and when drawn from the furnace and cast into short bars, or slabs, is designated pig iron.

For many years all pig iron was cast in open sand moulds in the floor of the casting house, and all iron cast in this way was known as pig, or pig iron. But since the introduction of new methods of casting the term pig iron has become general, and the pig is now designated by the manner of casting, as sand pig, chilled pig, sandless pig, machined cast pig, etc.

Sand Pig.

Probably ever since the beginning of the manufacture of pig iron it has been cast in open sand moulds in the floor of the furnace casting house. In preparing the moulds, perfectly level beds of sand are made and in these the pigs are moulded, a sufficient distance apart to prevent the sand between them from being washed or forced away by the pressure of the molten iron and the pigs from running together. At the end of each row or bed of pig, a perfectly level runner, or sow pig as it is called, is moulded. This sow pig is connected with the end of each pig, and one end of it is connected with an inclined runner constructed of sand from the tap hole of the furnace. Through this runner the iron is permitted to flow first to the pig bed, at the greatest distance from the furnace; when the moulds in this bed are filled, an iron gate or spade coated with clay is forced into the sand of the runner in such a way as to stop off the flow of metal, and another opening is made in the side of the runner by removing a shovel-

ful of sand, which permits iron to flow into the sow of the next pig bed. When this one is filled, the runner is again shut off at the next sow, and another opening made, and so on till all the iron in the furnace is cast.

The moulds are open sand moulds upon which no facing or blackening is used, and the pigs are heavily coated with sand burned on to them by the molten iron. This pig is now designated sand pig; the pigs are generally broken in the middle to show the quality of iron in fracture and for convenience in handling and shipping.

Chill Cast Pig.

The sand moulds above described required considerable labor to prepare them for each cast, and to save this expense, many furnacemen adopted a cast-iron permanent mould.

These moulds were cast in blocks of four to six pigs in a block with a sow pig attached and imbedded in the floor of the casting house. A sufficient number of them being placed side by side to give the desired length of bed or number of pigs in each pig bed. The molten iron flows through a sand runner from the furnace and the moulds or chills were filled in the same way as the sand moulds.

This method of casting had a chilling effect upon the iron which was very marked on the lower or harder grades of iron, due to the sudden cooling of the iron, which retained the carbon in a combined state when cold. This chill, whether light or heavy, gave foundrymen the impression that it was a hard iron, and it was seldom used by founders making light castings, and never became popular with foundrymen making any kind of casting, although it was a sandless pig and the chilled effect entirely disappeared when melted.

Very few of the furnaces making foundry iron adopted this method of casting, and it was principally furnaces making mill iron that used it. With the disappearance of the rolling mills, chill cast pig has almost entirely disappeared from the iron market.

Sandless, or Machine Cast Pig.

With the introduction of blast furnace and foundry chemistry, it was discovered that iron cast in chill or sand moulds was not of an even quality throughout the pig, and often through-

out the cast analysis showed different qualities of iron in different parts of the same cast, and in opposite ends of the same pig. This unevenness in the quality of the product was attributed to iron smelted from different ores, not having been thoroughly mixed before casting. To overcome this difficulty and produce an even grade of iron, a plan for mixing the iron before casting was devised. This was done by drawing the iron from the furnace into a large ladle capable of holding the cast to mix it before casting. From this ladle it is poured directly into the pig moulds, that are only about one-half the length of the ordinary sand pig. The moulds for these pigs are made of thin wrought iron, or soft steel, so they may be quickly heated by the molten metal. The chilling tendency upon the iron is thus greatly reduced and far less than that of the heavy chill used in chilling cast pig, and to still further reduce the chilling tendency they are coated with a carbon deposit or silicon wash.

These moulds are placed upon a revolving table upon which they are brought under the ladle to be filled and removed, to be emptied when the iron has sufficiently cooled to admit of this being done. They have also been placed upon traveling endless chains which carry them under the ladle to be filled and to any distance desired from the furnace, to be dumped into the yard or upon iron cars for shipment. This mode of casting being thus not only a labor-saving device in moulding the pigs, but also in removing the iron from the casting house.

Since the introduction of sandless pig into foundry practice, extravagant claims have been made for its superiority over sand and chilled cast pig as a foundry iron. This pig is generally cooled to a considerable extent by water thrown upon it, and shows a closer iron than sand pig of the same grade, and while an analysis of the iron has shown a more even quality throughout the pig and cast, this is probably due more to the even temperature at which it is cast, and the manner of cooling it, than to mixing it in a ladle before casting.

The extravagant claims made for the superiority of sandless pig do not appear to have been realized, for no better castings have been made from it, than from either of the other pigs when properly mixed and melted. All cast iron assumes its normal state when melted, and the chill on chilled cast pig, the closeness of sand pig at the tail end, all disappear when the iron is melted and do not appear again in it except from the causes that originally produced them in the pig. The manner of casting is therefore a matter of furnace practice, and has nothing to do with the quality of pig iron. It does not change its quality any more than

the shape of a casting and the manner of casting changes an iron when cast in a foundry. Foundrymen, therefore, should select their iron by quality and not by the shape nor mode of casting the pig. This may now be done by analysis, and an iron of a desired quality be thus obtained with more certainty than judging from the appearance of the iron.

A higher per cent. of iron is obtained from sandless pig than from sand cast pig, but this gain has been found to be so small that no higher price should be paid for it on this account.

This pig is quoted in the iron market report as both sandless pig and machine cast pig in different sections. But they are both the same pig.

Fracture Grading of Pig Iron.

In blast furnace practice the quality of the fuel, settling of the stock, atmospheric changes, etc., causes the furnace to work hot or cold, to such an extent that it changes the character of the iron smelted from the same qualities of ores and fuel, and makes grading of the iron of different casts, and sometimes of the same cast, necessary.

This grading has been done properly, since the beginning of blast furnace smelting, by taking a few pigs selected from different parts of the cast and breaking them in the middle when cold, and judging the quality of iron by its color and the size and shape of the crystals in the crystalline structure of the fresh fracture. This method of grading answered the purpose of furnacemen and foundrymen probably for hundreds of years, but with the introduction of foundry and blast furnace chemistry, analysis was found to more accurately indicate the quality of the iron than fracture indications.

This new method of grading has quite generally been adopted by furnacemen in the grading of iron, but pig is still quoted in market quotations by number, as in fracture grading, and a very large per cent. of foundry irons are still sold by number, but analysis indicates the number, in place of fracture indications.

This method covers the ground very thoroughly in grading for pig iron, and enables the furnacemen to deliver iron with more certainty as to quality than from fracture grading, but it does not cover the ground so thoroughly for foundrymen, for it is not practical for the foundrymen to have every pile of pig analyzed, and without a knowledge of fracture indications, be as

liable to charge a white pig for soft castings, and a number one soft pig for hard castings, if any mistake is made in the piling of the pig in the yard or upon the scaffold; nor is it practical to wait for analysis of castings, gates, or scrap, to determine the quality of the iron in a mixture. These are matters that must be decided off-hand in order to keep the plant running, and fracture indication is the most practical way of doing this.

Fracture Indications of Coke and Anthracite Iron.

In fracture grading of pig iron, the points to be looked for in the fresh fracture are, size and shape of the crystals, color of the fresh fracture, breaking, separation of graphite flakes in breaking, white edges in the fracture, etc.

The indication of a soft northern No. 1 pig, sand cast, are a large crystal, of a dark bluish color, from which small flakes of graphite may sometimes be seen to separate when broken. This indicates a soft, strong iron for casting of light section, but too open, porous and weak for castings of heavy section.

A large crystal of a light or silvery color also indicates a soft or weak iron, unsuitable for heavy casting. This color of crystalline structure is due to a high silicon or silicon having assumed a different form than found in the crystalline structure of darker iron, and light colored crystals are found in a few of the Northern No. 1 irons, but are more common in the Southern irons.

These irons are only melted alone or with their remelt, for castings of very light section, and even for stove plate they are generally mixed with a lower grade of pig iron or scrap iron, and are regarded as softeners.

No. 2 pig of both Northern and Southern irons present a similar fracture to those of No. 1, but the crystals are smaller and have a more compact appearance. No. 2 iron is classed as a soft iron, but a shade harder than No. 1, and a stronger iron. These two grades are frequently quoted as No. 1 and No. 1 X, No. 2 and No. 2 X. This means that the X iron is a shade harder than the plain No.

These two grades are the principal iron used for soft castings, of light and medium section. An increase of the No. 1 in mixtures gives a softer iron, and an increase of No. 2, a closer and a stronger iron, and when a still closer iron is desired, scrap is added to the mixture.

No. 3 pig has a still smaller crystalline structure than No. 2, and in some cases has a white thread-like streak winding through the crystals; it is then termed a mottled iron. This iron is readily chilled by damp moulding sand, and runs hard in castings of light section, but runs sufficiently soft in heavy castings for machining, and is principally used in mixtures for heavy castings as a strengthener, and making a close iron.

No. 4 pig is a very heavily mottled or white iron, having very little crystalline structure perceptible to the naked eye. This iron runs very hard, and is only used by foundrymen for hard castings or in mixtures to give chilling properties or closeness to the iron.

These four grades represented the standard grades for many years. A few years before the introduction of foundry chemistry they were increased to seven grades by number, or letter, but these were only subdivisions of the former four grades that required an expert grader to determine, and little attention was given to them by founders using anthracite or coke irons exclusively.

A spotted fracture, that is, a close spot in open iron, indicates an unreliable iron that may run hard or soft. These spots, or small crystals, have been attributed to melting mill cinder with the ores, but the rolling mills have nearly all gone out of existence, and these spots, when found, are now probably due to an ore in the mixture that does not mix with iron from the other ores when smelted. The spots generally disappear when the iron is remelted, but their effect may be to harden the iron. This can only be determined by melting the iron.

These instructions apply principally to the coke irons the foundries are most commonly using, and a careful study should be made of them and their application to the iron in the yard, that no mistake may be made in charging and melting an unsuitable iron for the work to be cast.

A white chilled-like edge of iron around a sand cast pig indicates the iron will run hard in light castings when remelted. The white edge around chilled and machine cast pig of an open iron disappears when remelted and does not again appear in the casting.

Cold Blast Charcoal Iron Fractures.

The fracture indications of charcoal pig differ somewhat from those of coke pig, the crystals are longer and sharp pointed, while those of coke iron are more of a diamond shape and flatter.

The color is always of a dark blue cast in the soft pig. The long, sharp crystals are an indication of strength, and the pigs are very difficult to break and frequently bend to a considerable extent from sledging before breaking. Small fragments may frequently be found drawn away from the iron but still clinging to the fracture; this indicates a very strong iron.

Cold blast charcoal iron is graded up to No. 7. This was done to enable malleable iron founders, car wheel founders, and others making hard or chilled castings to obtain exactly the degree of hardness they desired.

The No. 1 pig is a soft, strong iron, and has a long, sharp pointed crystal of a dark bluish color, and runs soft. In early days stoveplate and hollowware were cast of this iron direct from the blast furnace.

No. 2 has the same shaped crystal, but not so long or large. This pig has a strong tendency to chill and runs very hard in castings of light section.

No. 3 has a still smaller and sharper crystal than No. 2, is a very strong iron and runs hard in moderately heavy castings.

No. 4 is a mottled iron, light spots and lines like threads may be seen winding through the crystals, and from some furnaces it is a white iron. This iron, and also the No. 3, is principally used in mixtures to give closeness, or chill to the other two grades of soft iron.

The other three grades are all white irons, of different degrees of hardness, which is indicated by small crystals and different shades of color, which can only be noticed by comparison of fracture in grading. These three grades are used principally by founders in tempering the softer grades for malleables, car wheels, etc.

Hot Blast Charcoal Fracture.

The fracture indications of hot blast charcoal iron are very similar to those of the cold blast iron, with a long, sharp pointed crystal, indicating strength, the longer and larger ones indicating a No. 1 soft iron, and smaller ones a closer or No. 2 iron; while the still smaller crystals and white iron indicate a hard iron. This iron is only graded up to No. 4, which is a white iron.

Warm Blast Charcoal Fracture.

This iron has fourteen different gradings, and it would be very difficult to describe the distinct characteristics of the various

grades in an intelligent way. The crystalline structure is very similar to that of hot blast charcoal, but not quite so pointed and sharp nor drawn out in the fracture. But the indications of the large and small crystalline structure are the same for softness and hardness as those of the other charcoal irons, which may be considered in the study of the fracture of this iron.

Sandless Pig Fracture.

Machine cast pig are generally thinner than sand cast. Changed from the molten to the solid state more rapidly, and sometimes cooled by water thrown upon them, thus causing a smaller crystalline structure than seen in sand cast pigs of the same quality; but the change of structure from No. 1 to No. 4 pig is the same as in other pigs, and it is only necessary to become familiar with the crystals of the No. 1 pig to be able to read the indications of the lower grade by following the indications given for the different grades of coke iron.

Scotch Pig Fracture.

Scotch pig, both American and foreign, has a very long crystal, and is what is termed an open iron. It may have either a dark bluish cast, or a silvery cast; this is due to the form the silicon has assumed in the iron, and also to the higher or lower per cent. of silicon it may contain, but with either color it is a soft iron.

American Scotch is generally a No. 1 soft open iron. This iron is never graded below a No. 2 iron, as the term Scotch indicates a very soft open iron.

Silver Grey Fractures.

The fracture of a silver grey iron, and in fact all very high silicon iron, is of a silvery grey color, with a crystalline structure in which the crystals are larger in a lower silicon silver grey iron than in a higher. As the silicon increases the crystals grow smaller, until they almost disappear and the fracture is of a smooth, silvery grey appearance. This iron is very weak and very soft, although it has the appearance to some extent of a white hard iron.

The crystalline structure of these two irons is very similar in appearance to the naked eye, but under the glass they appear different. The main points of distinction in these two irons are

the silvery grey of the soft iron, and the white or mottled color of the hard iron.

Speigel-Eisen Fracture.

The fresh fracture of this iron shows cubes and plates, rather than crystals, and has a bright silvery mirror-like appearance. This iron is also indicated by its shape, as it is not cast in pigs of the shape of either coke or charcoal iron, but in slabs generally two to three inches in thickness, and eight to ten inches wide.

Other Pig Fractures.

Bessemer and basic pig have a very similar fracture to that of coke iron heretofore described. Malleable bessemer or malleable pig also have a coke iron fracture, but only the harder grades of this iron are used for malleables.

Scrap Irons

CHAPTER III.

Iron that has been cast into various shapes and forms, which are no longer wanted for the purpose for which they were cast, is designated scrap iron, or cast scrap. This iron, unlike pig iron, is not graded by fracture or analysis, but is classified as machinery, car wheel, stove plate, plow points, burned iron, drillings, turnings, malleable, steel, promiscuous scrap, etc. This classification is designed to take the place of grading, and indicates the quality of iron from which the castings were made and the grade of iron that may be found when remelted. It also indicates changes that have been effected in the iron after casting, in the process of finishing, or by the use to which the castings have been put before becoming scrap.

Machinery Scrap.

Machinery scrap is commonly classed as the very best grade of scrap, and this is the case so far as the iron is concerned, for it is cast from the best of iron for the purpose to which it is to be put, and no change is effected in the quality of the iron, in finishing the casting or by the use to which it has been subjected after finishing, and the same quality of iron is therefore to be found in this scrap as in the casting when cast.

But there is a wide variation in the character of iron required for different machines, and often for parts of the same machine, such as engine cylinders, gear wheels, etc., which are cast from rather close hard iron, that would run hard in light castings when remelted. Then there are parts of other machines, such as augers and jaws of clay and brick machinery; grinding disks of cement

machinery; crusher jaws, etc., which are cast of a white iron, so that while the iron in machinery scrap is as good as when cast, it represents a number of grades of iron and cannot be classed as a soft scrap or iron—neither can it be classed as a hard iron. This fact is recognized by stove founders and others making exclusively soft castings, and machinery scrap is not sought for by them. It is therefore necessary to sort this scrap before placing it upon the scaffold for charging, if an iron of a desired quality is to be obtained from it. Sorting may be done by indication of fracture, or by shape of the piece of scrap, and a knowledge of the quality of the iron from which such castings are made.

Machinery scrap is generally regarded as the very best of cast scrap for general foundry castings, and always commands the highest price. In some cases, when very select, it sells at even a higher price than a good grade of pig iron; this is due to the theory that a mixture of iron produces a better casting than any one iron, and by the use of scrap an endless number of irons may be obtained in the mixture and a superior casting produced. This is the theory and practice of many of the large engine works, and some of them would not make an important casting without machinery scrap in their mixture.

Car Wheel Scrap.

Car wheels are cast from a good grade of iron, which is not changed in finishing nor by the use to which the wheel is put before being scrapped. The iron in this scrap is therefore as good as when cast, and only a shade harder when remelted.

This scrap is of value with the addition of a small per cent. of pig for recasting into wheels, and is vary largely used for this purpose, as the railroad companies, in contracting for wheels, almost invariably specify that a certain per cent. of old wheels are to be taken in part payment for new ones. It is also extensively used in mixtures for mine car wheels to give a chill on the tread of the wheel. This iron is a very strong iron, with a tendency to chill when cast against a cold chill, but not so hard as to chill when sand cast, and is used in mixtures for castings requiring strength and closeness, to impart these qualities to the iron.

When placed upon the market, this scrap commands a good price, and sometimes sells higher than the price paid for new wheels, which, with the ordinary price of pig iron is only about

one cent per pound and generally a half cent below the price paid for brake shoes by the railroad companies.

Stove Plate Scrap.

This scrap is cast from a very fluid, soft, strong iron for castings of light section. It is not injured in mounting and finishing, but in the use to which it is put, it is subjected to prolonged and repeated heating, and some of the parts, such as the grates, fire pot linings, covers, etc., are subjected to so great a heat as to completely destroy the iron, while the iron in other thin plates is injured by the fumes, gas, rust, etc., to an extent that makes it a very poor iron when remelted, and owing to the large surface of this scrap exposed to oxidation in melting, the melting loss is heavier than on any other grade of scrap, which makes it the poorest and cheapest grade of scrap the founder has to deal with.

Only a limited amount of this scrap, taken in trade from their customers, is melted by stove plate founders, and even this is sometimes sold by them to other founders or junk men, as the desired quality of iron for plate is frequently not obtained from it.

It is most commonly melted by founders making a class of castings such as brake shoes, sled runners, sewer castings, etc., designed to be close, and upon which there is but little finishing to be done. When melted for finished castings it should be sorted and the burned castings thrown out, and only a limited per cent. of the better scrap placed in a mixture.

Plow Point Scrap.

Plow point scrap is generally cast from a hard iron with a tendency to chill, but not to chill to so great an extent as that of car wheel iron. This iron is not at all changed by the use to which it is put, and when remelted the resulting product is of the same quality, only a grade harder. This scrap is so widely distributed that it is only classified at foundry centers surrounded by a large farming district. It commands a fair price to remelt for this line of casting.

This scrap is made from an excellent grade of iron, and may be melted with pig for any grade of close castings, but its tendency is to chill in very thin castings. This may be overcome

by melting with it a pig containing sufficient silicon to insure it running soft.

Promiscuous Scrap.

In all large cities and foundry centers, scrap is generally handled by junk or old iron dealers, who sort it and prepare it for the various grades previously described. When the character of the scrap is not clearly indicated by the shape of the castings, or there is not sufficient iron to market it separately, it is thrown into a pile that is designated promiscuous scrap. This scrap is generally small, of an inferior quality, and sells at a lower price than graded scrap. It is used by foundrymen for the class of castings upon which there is little finishing to be done, and in which the quality of iron is not of any great importance.

In districts where the amount of scrap is limited, there is seldom sufficient of any one kind, collected by dealers, for sorting into car loads, or even wagon loads, and it is all sold together as promiscuous scrap. This is an entirely different scrap from that above described and may consist of heavy and light cast scrap, wrought iron, steel, malleables, etc. This scrap may be sorted by the founder in the yard, when loading for the scaffold and several grades obtained from it. At a small foundry in Maryland, the foundryman was able to make castings from almost entirely selected scrap, that filled all the requirements of a United States Government specification, and also to make soft castings with a limited amount of pig, and close or hard ones without the use of any pig.

A knowledge of the analysis of the various lines of castings and characteristics of the iron may be gained from the analysis of castings to be found in this work, and when such a knowledge has been gained and the sorter becomes familiar with the shape of different lines of castings it is an easy matter for him to sort from this scrap an iron suitable for almost any line of casting.

Steel Casting Scrap.

The manufacture and use of steel castings for a large variety of purposes has become so extensive of late years that this scrap constitutes an important factor in promiscuous cast scrap for grey iron foundry castings. When separated from this scrap it is of no value whatever to the grey iron founder for melting alone, as it is only fit for sash weights when melted, and is difficult to melt alone. Malleable scrap found in this scrap gives about the same results as steel scrap, when melted alone.

Steel and malleable scrap are very difficult to separate from promiscuous cast scrap, as it is generally small, and frequently painted and can only be separated by breaking, until one becomes familiar with the shape of the steel castings commonly found. When separated, it may be melted for hard castings, or in the making of semi-steel, but for semi-steel this metal is not as reliable as the forged or rolled steel.

When steel scrap is mixed with cast scrap to a considerable extent it has a hardening effect upon the latter, and when only a small per cent. is present it may cause hard or close spots in casting. I would not advise the use of promiscuous scrap containing steel in mixtures for finished castings, but a promiscuous scrap, containing both steel and malleable scrap, may be melted for common castings, and better results will be obtained in softness and evenness when a high silicon pig is melted with it.

Malleable Scrap.

Malleable scrap is a white hard iron when cast, that has been annealed by the malleable process of annealing, and converted into a malleable iron, which is a soft, strong iron, almost entirely devoid of carbon and resembles wrought iron in strength and ductility.

This iron, when remelted in a cupola, does not retain the characteristics of malleable iron, but absorbs carbon from the fuel and returns to its original form before annealing—that of a white cast iron, with most all of its carbon in the combined state. This is the kind of iron that is obtained from malleable scrap when melted alone. When melted with soft scrap or pig, it has a hardening effect upon the soft iron, varying in degree with the quantity of malleable scrap used in the mixture with the soft iron.

For many years grey iron foundries carefully avoided purchasing this scrap, and when found in cast scrap threw it out. Malleable foundries also did not desire it in their mixture, and it was sold to rolling mills at a very low price to be melted in mixtures with wrought scrap for wrought iron, but of late years malleable foundries have been melting it more freely in their mixtures, and since the introduction or discovery of high silicon iron, foundries do not object to a limited amount of it in their scrap, except when castings are required to be a very soft iron, and then very carefully excluded it, as they do all other hard iron.

I have never learned of a heat being melted exclusively of this scrap, to determine its loss in melting. But as it absorbs carbon freely when melted with a silicon iron, the loss in melting is probably not very high, if any.

Wrought Iron Scrap.

Wrought iron scrap, when abundant, was quite extensively used by foundrymen in their mixtures as a strengthener of their iron, but of late years it has become so scarce that it is scarcely worth considering for this purpose.

Patents were taken out in England in 1846, by Mr. Sterling, for toughening cast iron by adding wrought iron to it in melting. In his experimental work he found that the per cent. of wrought scrap that gave the best results, depended upon the quality of the cast iron scrap or pig with which it was melted, that is, it depended upon the per cent of silicon the cast iron contained, but as there was no such thing as chemistry of foundry iron at that time, there is no data obtainable on this point.

Mr. Sterling's experiments covered the melting of from 10 to 60 per cent. wrought iron scrap with 90 to 40 per cent. cast iron and noting the increase of strength as the wrought iron was increased. In these tests, he found that the maximum strength was reached with 30 per cent. wrought scrap; above this per cent. the strength began to decrease, and he set 30 per cent. wrought scrap with 70 per cent. cast scrap or pig as a standard for the highest strength.

This scrap is a commercially pure iron, and there is no reason why it should not act as a purifier and strengthener of cast iron, the same as steel does in semi-steel. But in melting it with cast iron, a higher silicon iron must be melted with it, to induce it to take up carbon and bring it back to a cast iron. If this is not done, it does not properly unite with cast iron when melted, and causes hard spots and small blow holes in castings. When such a condition is found in castings due to an unknown cause, it may be due to this scrap in the mixture and the silicon in the mixture should be increased.

Foundry Scrap.

This scrap comprises the remelt in foundries, such as gates, sprues, runners, sink heads, over iron, cupola dump iron, bad castings, etc.

This scrap is of the same grade as that in the castings for which it was melted, whether hard or soft, and is available to melt again for the same line of castings. When remelted, it runs a shade harder; this can readily be prevented by melting with it in the mixture a sufficiently high per cent. of a soft high silicon iron to insure it being as soft as when first melted. This is the common practice in foundries, but some few of them do not seem to follow this practice, but sell their bad castings to other foundries as scrap, while other foundries sell all or part of their gates and other remelt. At one foundry I visited the past year I was shown a carload of bad lathe chuck castings which they had just gotten in from another foundry. These were all bad castings, many of which had been partly machined while others had been condemned after cleaning.

At another foundry I learned they were selling a large per cent. of their gates to other foundries as scrap.

The selling of this scrap is the poorest kind of foundry practice, for it is worth the cost of the mixture, from which it was made, for remelting it, and when sold as scrap it is only worth from one-half to two-thirds of this cost, and there is a direct loss to that extent.

The reasons usually given for selling this scrap are that the iron runs dirty in the castings, or that the remelt hardens the iron to an extent that makes it too hard for the casting. The first reason is not valid, for if an iron is proven to run dirty and unfit for the castings in two or three heats, its use should be discontinued at once, or a change effected in the mixture that will overcome this trouble, or a flux used that will clean the iron. If the remelt renders the iron too hard for the castings, a change should be made in the mixture, so that it will carry its remelt. This may be done by increasing the per cent. of pig in the mixture, or by placing a higher silicon pig in the mixture as a softener. In this way all remelt scrap may be melted and should be melted each heat, and not allowed to accumulate in a foundry.

Shot Iron.

This foundry scrap comprises all small particles of iron recovered from the cupola dump gangway cleanings, top of moulds, etc., and I shall include with it fins, vents, shell from runners, ladle sculls, and all very small irons collected from the foundry.

Some foundries consider this iron of so little value that they throw out the dump, all of the cupola dump, after picking out the

larger pieces, and treat the gangway cleanings in the same way; while others shovel it into a stave tumbling barrel and permit the smaller particles to escape through the cracks between the staves with the sand and other refuse, only recovering the largest pieces of iron, claiming that the very small particles are all burned up in remelting, and that the larger pieces have a hardening effect on the iron in the heat.

That this iron had a hardening effect upon the iron charged with it in melting, and that the greater part of it was lost in remelting was the opinion of foundrymen for many years, and numerous plans were devised and patents taken out for excluding the blast from it so as to reduce loss in melting and prevent hardening. Among these devices was the placing of the shot in cast iron pots tightly covered; also in open pots; melting it in closed tubes or pipes; charging it in wooden boxes; pouring molten iron over it; in pig beds to inclose it in the pig; placing it in ladles and tapping molten iron upon it, etc. But all these plans proved a failure, and the iron was either thrown away or melted in the last charge for weights or other common castings in which the quality of iron was not an important matter.

With the introduction of foundry chemistry, and a more complete knowledge of foundry irons, the hardening effect of this iron has been completely overcome by an increase of silicon in the mixture, and although the heavy loss in melting still continues, this iron is regularly melted in heats for the various lines of castings.

Since the discovery of this new and more satisfactory method of melting shot iron, new methods of recovering it have been devised. One of these consists of a series of riddles, placed one above another, the upper or coarser riddle recovers the larger pieces, and the lower one the smaller pieces. This machine recovers all the iron, but it is necessary to break up the cupola dump before placing it in the separator. This is done in a stave tumbling mill, and the larger pieces recovered and only the refuse that escapes through the opening between the staves is put through the separator to recover the smaller particles of iron.

Another device is the magnetic separator. In this case, as with the riddle separator, the material is broken up in a tumbling barrel, and only the refuse that escapes from the barrel is put through the separator. As it passes through the separator the magnet recovers every particle of iron, and also considerable slag or cinder adhering to the iron. And in some cases, slag

heavily impregnated with iron in combination that cannot be recovered in melting. A pile of iron recovered by this means is therefore deceptive, and may contain very little iron.

Probably the best method of recovering from this iron is by means of a water tumbling mill, of which there are a variety of designs on the market. Probably the oldest of these mills is the Sly Mill, made by The W. Sly Mfg. Co., Cleveland, Ohio. This tumbling mill consists of a water-tight steel tumbling barrel, into which the cupola dump or other refuse containing iron is thrown. Water is forced into one end of this barrel and flows out at the other end, the revolving of the barrel breaks up the dump and frees the iron from the cinder and slag, which is washed out by the water, leaving the iron perfectly clean and free from slag. All small pieces of coke are also washed out by the water and separated from other refuse by a revolving screen attached to the end of the barrel. This coke is so small that it is of little value as a cupola fuel, but it may be used for core ovens, heating the foundry in winter, etc. It makes an excellent stove and range fuel, and any surplus may be sold to employees for this purpose.

The best method of melting shot iron, yet discovered, is to charge it loose into the cupola, with the regular charges of iron, placing one or more shovels on each charge of iron, so as to divide it up evenly through the heat. When only the shot from the previous heat is melted in this way, its hardening effect, if any, is so small that it is not perceptible in the castings.

This iron should never be permitted to accumulate about a foundry, but all that from the previous heat, gangway, etc., melted every day when bright and clean. That from the gangway should be put through the tumbler with the dump, to clean and remove rust from it, for rust greatly increases its hardening tendency.

When this iron is permitted to accumulate, to be melted separately, for weights and other castings, it becomes heavily coated with rust and the smaller particles are completely destroyed; thus the per cent. of iron recovered from the larger pieces is very small compared with the amount recovered if new and clean when melted, and the iron is very hard.

I met a sashweight founder a few years ago at Indianapolis, Ind., that was offered a fifty-ton lot of rusted shot iron for three dollars per ton, when the cheapest of scrap was selling at twelve dollars per ton. He refused to buy it, even at this low price, giving

as a reason that, when melted, nothing but slag could be obtained from it.

Turnings and Borings.

This is a machine shop scrap, cut from castings in machining by lathes, planers, boring mills, drill presses, etc., and consists of very small chips or particles of iron, some of which are as small as iron filings.

The market value of this iron, when new and clean, is only about one-fourth that of the pig or mixture from which it is cast, and in many sections of the country is not salable, even at this low price.

Foundrymen have reasoned that this iron was cut from soft castings, and was therefore a soft iron and available for melting and casting again for soft castings. Many attempts to melt this iron alone in a cupola have been made, in all of which only a hard iron was obtained from it. It has also been melted in cupolas with pig and scrap mixtures, in which case it was found to have so great a hardening effect upon the iron, even with a low per cent of it, that this plan had to be abandoned.

The hardening of this soft iron is due to the oxidizing effect upon it by the heat and blast of the cupola, in the teaching of chemistry, one of the illustrations of oxidization is the burning of iron filings in the flame of a candle. In this illustration, the filings are taken between the finger and thumb and slowly dropped upon the flame, the smaller particles are instantly burned, with a bright spark, into a black oxide of iron, while the larger ones drop through the flames unburnt, owing to the heat not being sufficiently intense to burn them. The effect of heat and oxygen upon turnings and borings in a cupola is similar to that of filings in the flame of a candle, but the heat being more intense and the supply of oxygen more abundant, burns all the smaller particles to an oxide, and the larger ones to such an extent before melting that only a very hard iron is obtained from that not totally converted into an oxide and the loss of iron in melting is very heavy.

To reduce the loss in melting and procure from this metal a soft iron, all the various schemes for melting shot iron have been tried out, and also various other plans designed to exclude the blast from it before melting.

It has been placed in the cupola loose with each charge of iron, and apparently melted with no hardening effect, but after

a few heats, the foundry roof is found to be covered with black chips, evidently none but the larger chips having been melted. When charged in the cupola in heavy layers alone, it was found the blast did not pass through it, but worked its way up around the edges, and the destruction of cupola lining was heavy, and the iron burned off the edges of the mass very hard.

A light layer was placed upon the bed and iron from it used to warm ladles, and poured into the pig bed. This method frequently left a scum of hard iron in the ladle, that hardened the first ladle of iron and it also was found to clog the bed and retard melting throughout the heat.

It has been charged in bulk into the cupola on top of the regular heat to be melted and run into pig and also charged into the hot cupola after the heat was melted to be melted in pig; neither of these plans proved a success in getting a soft iron.

It has been placed in the bottom of ladles to be melted by the molten metal direct from the cupola, but it was found to ball up or mat together in the bottom of the ladle, and could not be melted from a small bull ladle, many times filled with hot iron, during a heat. A very little of this iron can be melted in this way, but not a sufficient quantity to make it practical.

Attempts have been made to place this iron in pigs to be remelted, by placing it on top of the molten iron in the pig bed, and placing it between layers of iron by partly filling the pig with molten iron and placing turnings upon it, while in a molten state and pouring more molten iron on the turnings, and in this way build up a solid layer of pigs and turnings. This method was found not to be practical, as only a very small per cent could be incorporated in the iron.

Another scheme was to make a pig bed of these turnings, in place of a sand bed. It was hoped by pouring iron into this bed to melt the turnings and incorporate them with the iron. But the turnings were not melted by the iron, and only a very limited amount adhered to the pig, and the greater part of this fell off in handling before reaching the cupola for remelt.

New Methods for Melting this Iron.

The following notice appeared in a foundry paper a few years ago: "A process for charging and melting borings, turnings, etc., in the cupola, to insure the melting of this material with regular pig and scrap charges, and to prevent the same particles from being blown out of the furnace, by the blast, has

been patented by Walter F. Prince, who is in charge of the foundry department of The International Steam Pump Co., Elizabeth, N. J. The material consisting of borings, drillings, or any other small particles of iron is charged in wrought iron pipes, preferably, number 18 to 24 gauge and varying in length from 3 to 4 feet. This casing may be open end cylinders or may be closed at one end, so as to hold the borings independently of stacking the castings. The transmission of heat through the pipes brings the borings into condition to readily melt down with the rest of the cupola charge. The entire charge of material in the furnace therefore settles down uniformly and as the charge on top is continued, casings are added and filled with borings or drillings as designed. The first section of the pipe containing borings or drillings is charged on the coke bed, and other sections are added as the charging continues, while only one stack of casings is referred to, any number of stacks may be used in the cupola, according to the results desired."—The Foundry.

Upon visiting the Worthington Plant, at Harrison, N. J., I met Mr. Prince, who very cordially explained to me his system and showed me his method of operating it. He was melting in a 72-inch cupola and for his borings was using a 12-inch diameter sheet metal pipe in 3-foot lengths. These pipe lengths were put together like stove pipe, and the end of the pipe set on the bed in about the center of the cupola, and filled with borings up to the charging door. The charges of iron and coke were placed in the cupola around this pipe in the regular way, a small charging door had been placed in the cupola above the regular charging door, and a platform erected for charging the borings so that this charging might be out of the way of the men charging the coke and irons. When the blast was put on, and the iron began to melt, the borings and pipes also began to melt at the end on the bed and settle with the stock, as the pipe settled another length was put on, and filled until all the stock for the heat was charged. Only one pipe or stack of pipes were being used but as many as desired may be placed in the cupola. The cost for pipes in this case was one dollar and twenty-five cents per ton of borings, and the value of the iron recovered claimed to be equal to the value of the iron in the mixture of pig and scrap. The pipes used were made of number twenty-four gauge sheet steel, and of a diameter to suit the size of cupola and heat melted that only one stack might be used and the desired per cent. of borings melted. But ordinary stove-pipe of a diameter to carry the per cent. of borings may be used, and desired number of stacks placed in a cupola.

Mr. Prince was able to show very satisfactory results in analysis, strength and machining properties from borings, melted in this way, in his regular mixture. The entire output of borings from this plant, which amounted to from five to ten per cent. of the heat, was being melted in this way each day.

German Method of Briquetting This Metal.

A machine shop handling about three thousand tons of iron castings a year, has from two hundred to two hundred and fifty tons of scrap iron and steel turnings which it can sell to the foundry for briquetting. Some foundries bought the scrap and tried to melt it in cast iron pipes, pots or boxes, but gave it up as it was too expensive. The same was true of those foundries using wooden vessels, as the price of lumber forbade that practice.

Briquetting this scrap was also tried, but it was found that to do this a binding material was used which was high in cost and had an injurious effect upon the castings.

For use in cupolas only briquettes of the following description can be used:

First, they must consist of pure iron and steel chips.

Second, they must have sufficient firmness.

Third, they must remain firm until they are melted.

Fourth, they must be low in cost.

All of these requirements are met by briquettes made by the Ronay Process. In this process the chips are dumped into a bin, and are conveyed by belt conveyors and elevators to the magnetic separator, where dirt and scale are removed and then go to the blast where the last tracings of dust are blown out. They are now delivered to the press where they undergo varying pressures, going up step by step, and ending with a pressure of from 23,000 to 30,000 lbs.

By this process and the special air removing process which removes latent air from the briquette, a product is obtained which contains practically no air, and has very great firmness.

The presses are hydraulic rotary presses of special design. The various sorts of material used are steel, cast iron, grey iron, cylinder iron and scrap in general. These are worked and treated in separate bins, so that the composition of the different briquettes can be varied at will. This is especially useful for foundries

without laboratories, as the foundry manager can always figure out the composition needed and get just what he wants.

Tests have shown that in the iron in briquette combinations, used in cupolas, the carbon is very low. This loss is explained in the following way: the structure of the briquette, though very compact, is not completely so, and is porous to a certain extent—porous enough to allow gas from the furnace to penetrate through the mass; when this takes place, the carbon in the briquette, which is there in the form of graphite, is burned. As the process goes on, the decarbonized iron takes up fresh carbon, but the time in which this is done is so short, that the iron cannot take up sufficient carbon to make up the loss; we get, therefore, iron with a low carbon percentage, which, however, is very strong and gives a good grain to the casting. The carbon percentage can also be lowered by the addition of 5 to 15 per cent. of steel, but usually there is so little silicon in the iron, that the castings become hard and difficult to machine and finish. In which case, a low carbon special iron must be added.

“With the use of briquettes such special iron is not needed. With the right briquetting proportions the most sensitive parts can be cast, such as locomotives and pump cylinders. This combination iron can also be used for castings of great strength, where thin walls are necessary, or castings making sudden changes of cross section, as gear teeth and wheels. In machine and lathe castings, where fine grain is wanted, this iron will be found useful. In practice, the combination of iron with 20 to 40 per cent. briquettes has proven efficient.”

“Briquetting of metal chips is important, as it saves money and is much more economical than the ordinary process of melting metals in crucibles. The briquettes can also be used with other metals in cupolas, or else can be used separately and will give good castings. On account of the uniform weight, they are easily controlled in the stock room, and the loss in conveying suffered from loose metal chips is entirely eliminated. The process can be used for brass, copper, aluminum, white metal and other metals.”—*Giesserei Zeitung*.

Pressure Briquetting.

The General Briquetting Co., 25 Broad Street, New York City, N. Y., had on exhibition at the Boston, Mass., convention of The American Foundrymen's Association sample briquettes of borings and turnings made under pressure. These were made in a cylinder, into which the borings were placed and subjected

to a pressure of 30,000 lbs., which pressed them into a solid block, having the appearance of one solid piece of iron, and showing no outward indications of being small turnings or borings or chips of iron. Samples of mixtures melted, containing these briquettes, showed that as high as 30 per cent. of these briquettes have been melted in a mixture. A five per cent. bar showed a very close iron, and a ten per cent. mixture showed a very close iron with a decided tendency to chill, and this appeared to me to be about the limit that could be melted in mixtures for soft castings. Parties wishing to learn more about this manner of briquetting can do so by addressing the above firm.

It will be noticed that in the German description, it is stated that the carbon which is there in the form of graphite is burned. As the process goes on, the decarbonized iron takes up fresh carbon, but the time in which this is done is so short that the iron cannot take up sufficient carbon to make up the loss. We get therefore an iron with a low percentage of carbon.

This statement indicates that this iron is much harder than before melting, and that the production of a soft machinable iron was not obtained by briquetting.

The exhibition of briquetting at Boston convention did not show any sample of briquettes melted alone, those shown containing 5 per cent. briquettes in a mixture showed a very close iron, and those containing 10 per cent. showed a decided tendency to chill.

Although compressed briquettes are a solid block of iron, showing no outward indications of being turnings and borings, they are said to fall to pieces when heated to about 800 degrees Fah.

Binder Briquetting.

"The use of cast iron borings in cupola has always involved great difficulty in view of the fact that the heats rarely ever show that any of the material so charged has been recovered. This either indicates that the borings have been blown out of the cupola by the blast, or that they have been oxidized and carried away in the slag. Various methods of charging the borings have been tried, but it seems that briquetting this material brings the most satisfactory results. A mould for these briquettes made from ordinary lumber, tapering from 13 x 7 inches at top to 12 x 6 inches at the bottom, will form briquettes weighing from 50 to 55 lbs. each. A tapered mould is preferred as the briquettes can more easily be removed from the boxes.

"The material is mixed with briquetting compound or binder, manufactured by the O. Obermayer Co., Cincinnati, Ohio, and is thoroughly mixed in a dry state, sufficient water is added to temper the mixture, in practically the same way that an ordinary core mixture is prepared. The borings mixed with the compound are then compressed in the mould by use of either compressed air or a hand press. A jar ramming or squeezer moulding machine can likewise be used for this work. Approximately 50 lbs. of briquetting compound are used per ton of borings. Briquettes, before using, should be permitted to remain in a temperature ranging from 75 to 80 degrees Fah., for a period of forty-eight hours, when they are ready for use. When charging these briquettes, they should not be placed upon the coke bed, but should be included in the subsequent charges. The borings should be charged on the top of the scrap before the coke is added. Approximately 10 to 15 per cent. borings may be used to each cupola charge."—The Foundry.

The above appeared in "The Foundry" a few years ago, and shortly afterward I visited a foundry at Waterloo, Iowa, that was trying out this briquetting compound, and learned that the compound had a heating effect upon the briquettes and that they remained warm for 48 hours after briquetting, and did not form a hard solid block of iron before being ready for charging, but could be crumbled off with the hand, and they probably went to pieces as soon as heated. The foreman stated the melting of these briquettes had been a success, but on visiting the plant some time later, I learned that they had discontinued briquetting and melting this iron as it had not proven satisfactory.

Other Methods of Briquetting.

Mr. Lewis Baden, foundry superintendent of The Niles Tool Works Foundry, Hamilton, Ohio, reports the successful melting of this iron by mixing it with a sufficient amount of Portland cement to hold the iron together when set. The cement is wet and mixed with the turnings, the mass is then rammed into an iron pig mould, from which it is readily removed when the cement has set and formed with the iron a solid mass. The pigs are then piled to dry for a few days, and when dry are charged into the cupola with the regular mixture of iron for the heat. Mr. Baden reports very satisfactory results with 10 per cent. of this iron in their regular mixture of soft machined tool castings. A hard iron with 20 per cent., a still harder one with 30 per cent., and one too hard to be machined with 40 per cent. Two bags of cement are sufficient for a ton of borings.

Mr. David Spence, foundry superintendent of The Dayton Motor Works Foundry, North Dayton, Ohio, obtained results similar to those of Mr. Baden, in melting this iron, by mixing it with plaster of Paris and forming it into pigs, but did not continue to prepare and melt the iron in this way for any length of time.

In briquetting with either of these materials, the smallest possible amount of binder that will hold the iron together should be used. For if too abundant they retard the melting and tend to clog the cupola if many briquettes are melted in a heat.

Chattanooga Method.

A foundryman at Chattanooga, Tenn., informed me that he had melted borings very successfully by taking off the blast as soon as his iron was all melted, and charging a ton of borings into the hot cupola without extra coke and putting on a mild blast, after the borings had been in fifteen minutes. This method, it was stated, produced a very close or mottled pig which was used in cylinder mixtures to close up the grain of the iron. The cupola was a fifty-four inch one.

W. F. Keep's Method.

Mr. Keep, in answer to an inquiry as to the best method of melting borings, answers in "The Foundry" as follows:

"I would advise spreading the borings over the sand bottom before the kindling is put into the cupola. They should be spread approximately one to two inches thick. This charge of borings will be melted by the first iron that comes down and will not injure the mixture. By experimenting you can soon ascertain how thick a layer of borings can be melted."

It is well known that a layer of this iron one to two inches thick in a ladle cakes up and cannot be melted out with a ladle many times filled during a heat. This would probably be the case in a cupola, in which event, it would hang up the entire dump. The first iron melting and falling upon this solid iron in drops would be chilled, and with the slow melting of the cupola at the start might be chilled to an extent that it could not be tapped. At any rate, the first tap would be dull iron, with a possibility of dull iron throughout the heat.

R. P. Shaw's Method.

In answer to inquiries made in "The Foundry" regarding the best method of melting cast iron borings in the cupola, R. P.

Shaw says: "I have a suggestion to offer that has given me excellent results in the past. When charging the cupola I usually lay about 200 lbs. of small scrap evenly upon the bed of coke, on top of this layer I charge from one to two hundred pounds of borings, I then complete the charging of the furnace in the usual way. The weight of the pig iron being sufficient to prevent the borings from being blown out of the stack. Some borings are, of course, lost in this way, but the speed of the blower can be regulated and the blast can be kept down to eight or ten ounces."

"Before belding in the last two charges it is advisable to reduce the speed of the blower about one-half, as the greater loss will occur at this time if the furnace is not properly controlled."

"Another method that has given good results provides for the charging of the borings when the furnace is running low and after the moulds have all been poured. The entire charge of borings, amounting to two thousand pounds can be made and can be melted with a small amount of coke, as the furnace is hot enough at this time to almost melt these particles of iron. This iron will be suitable to run into the pig bed."

The melting of this iron in bulk upon the bed and in charges has already been described with results obtained. It can be melted in a hot cupola at the end of a heat, and a close or mottled iron obtained from it, if there is a good bed of coke in the cupola at the end of a heat. If the coke is almost exhausted it cannot be melted at all, but combines with the slag and bungs up the cupola. It will be well to remember these two "ifs" when making this test.

Piping Borings.

Borings are now being put up in joints of stove pipe at Bridgeport, Conn., and other New England towns by machine companies and sold to foundrymen for melting. About a four-inch pipe is used, and a head is put in each end and the pipe battered down over it to hold it in place. These pipes, charged into the cupola on top of the pig iron, melt rapidly, and are said to give a very satisfactory metal in a proper mixture.

This system of melting borings has been practiced in Hamilton, Ohio, for a number of years, and gives very satisfactory results in mixtures for heavy cylinders, in which a small per cent. is used to give a very close metal. When melted alone in this way, it gives a white or mottled metal, and in no case that has

come to my knowledge has this iron been melted to produce as soft an iron as when originally charged into the cupola.

My Own Tests.

I have made many tests in melting this metal, and also learned of others having made similar tests which proved satisfactory, but I have never learned of any of them continuing to melt it for any great length of time.

One of the most extended tests I ever made in the melting of this metal was at the foundry of Bement & Miles, Philadelphia, Pa., some twenty-five years ago. In these tests the borings were put up in rough wooden boxes, holding one hundred pounds each, the boxes were charged with the regular mixture to an extent of 5 per cent. of each charge. The borings melted and mixed with the other iron and produced a very satisfactory iron for machining for about a month's time. At the end of this time, a long lathe bed was cast, and when lifted from the sand, about six feet of it dropped off one end from its own weight. An inspection of the fracture showed a white, very hard, weak iron, that could not be touched with a tool, the borings had evidently not mixed with the other iron, and all flowed into this part of the casting. This ended the tests and melting of borings at this plant.

I have met other foundrymen who had a similar experience in melting borings, and even with the Prince Process, a foundry at Milwaukee, Wis., had a five-ton cylinder split open from end to end due to the boring iron not mixing with the other iron. But this was attributed to the pipe, in which they were charged, bursting and the borings not being melted at the end of the pipe. I have found that this iron may not only concentrate in one place, but also that it runs spotted when mixed with soft iron, and becomes what is known as a sandwich iron, that is, has no fibers extending into the soft iron.

My best results in melting this iron in a cupola have been obtained with about 5 per cent. borings, above this point its hardening tendency is very great, and 10 per cent. is about the limit that can be used with an ordinary foundry mixture without having the iron too hard for machining. Even with 5 per cent. of borings, the tendency to harden a soft iron is very great, and when borings are mixed with a soft iron, the silicon should be increased in the mixture to insure the castings being soft.

The melting of turnings and borings has always been an attractive proposition to foundrymen, and probably more time

and money has been spent in devising and trying out various plans to melt this iron than any other proposition that has come before them without obtaining the desired results. I have therefore gone into this matter in detail, that foundrymen may know what has been done, and not go over the same ground again with no better results.

It is a common practice in machine shops where this iron is not salable to throw it out in a heap to rust and be destroyed. This is a waste of very fine sidewalk or runway material, for by wetting it with a little salammmoniac water or a very thin cement, and ramming it down in a layer several inches thick, it rusts into a solid block of iron, and makes a runway for wheel barrows in the foundry yard that never wears out, and a bed of ashes or cinder under it prevents it being thrown out of shape or broken up by the frost. It also makes a fine floor for scrap bins, and may save many small pieces of iron commonly trampled into the ground.

Steel Turnings and Borings.

I have never learned of these turnings and borings having been successfully melted in a cupola, although many attempts have been made to melt them by the various plans described for melting iron turnings and borings. These turnings are so light and borings so small that probably the greater part of them are burned up by the intense heat of the cupola, and very little metal has been recovered from them when melted alone, and this was extremely hard.

Mr. Prince claims to have melted them successfully by his pipe plan when mixed with iron turnings in a limited quantity, but this is a matter that is very difficult to determine, whether they were melted or burned up.

But they may be melted by dropping the long ribbon-like turnings into a ladle of very hot iron. In this case they should be dropped into the molten iron from the hand very slowly, and evenly distributed over the surface of the iron. When this is not done and they are put in from a shovel or too heavy a layer put in by hand, they ball up, and are difficult to melt before the iron becomes too dull for pouring. About 5 per cent. thin, clean turnings can be melted this way in good hot iron and they have a very decided effect in closing up the grain and strengthening the iron.

It is a common practice in many jobbing foundries to treat iron in this way when only a limited amount of close, strong iron is required for casting.

Bins for Pig and Scrap.

It is common practice to throw pig iron upon the ground when unloading cars in the foundry yard, and by a second handling place it in piles, and place a sign upon each pile to indicate the make and grade of the iron. This conserves the room in the yard and makes it look very neat but with the present high price of labor it is quite expensive.

It is also common practice in unloading scrap to throw it upon the ground where it sinks into the soft earth in wet weather, and small pieces in breaking are trampled into the ground and lost. Where this practice has been followed for years, tons of this small iron may be found buried in the ground. To save the expense of piling pig and loss of scrap iron, bins may be constructed for both pig and scrap.

When visiting the Walker Foundry Co. Plant, Erie, Pa., last month, I found a very complete set of bins for pig and scrap. These bins were constructed of old railroad ties set on ends close together with one end sunk into the ground about two feet and fastened together at the top with a two by four studding on each side bolted together. This formed a stockade that could not be moved or destroyed by pig iron thrown against it from a car. Each bin was of a size to hold one or more cars of pig or scrap. A partition of ties between the bins served to separate the different grades and brands of pig, and no further piling was necessary, as each bin was marked with the brand or grade of iron. A good solid floor was placed in each bin which prevented both pig and scrap sinking into the mud and being lost.

Chemistry

CHAPTER IV

Chemistry is a very old science, as there is evidence of it having been practiced by many of the ancient nations under various names, but it does not appear to have been applied to the manufacture of iron or its manipulation to any great extent until about the time of the issuing in England of a patent for the making of what is now known as Bessemer steel in the year 1855. From that time on its development in this direction was rapid, and it now probably covers every branch of the iron industry of the entire world.

In this country chemistry was only employed in the making of steel until about 1876. About this time furnace men began to analyze their ores, and some of the car wheel founders employed chemists in their efforts to find a substitute for cold blast charcoal iron which was becoming very scarce for car wheel making. This research met with so great a success that Dr. Dudley, the chemist of the Pennsylvania Railroad Co. in 1878, took up this research work, and numerous analyses of pig iron used in the making of car wheels and also the analysis of the wheel were made at the foundry of this company located at Altoona, Pa. After the publication of the results obtained by Dr. Dudley more interest was taken in the chemistry of foundry iron, some of the larger foundry companies fitted up laboratories and employed chemists who had been employed by steel plants and had some experience in the analysis of pig iron, to determine its suitability for steel making. Blast furnacemen also began analyzing their ores and iron about this time, but progress was slow, and it was not until 1882 that the prediction was made in print that the time was coming when pig iron would be sold by

analysis instead of fracture indication—the method that had been followed for hundreds of years.

It was not until 1890 that this prediction was realized, and not until about 1895 that chemistry was adopted by foundrymen to any considerable extent in determining the quality of iron in their pig, and foundrymen applied this knowledge in the making of mixtures for their castings. About 1900 the American Foundrymen's Association and various local foundrymen's associations took up the matter and every facility was offered to chemists to make the chemistry of foundry iron a success. That their efforts were both a failure and a success must be admitted, for they failed to produce from anthracite and coke iron an iron having the superior qualities of a charcoal, hot or cold blast, pig iron, as it was hoped to do, but they have succeeded in producing from these irons, with a greater degree of certainty, an iron having the desired degree of softness, hardness, density, strength, etc., than was formerly done from fracture indications.

Blast furnace chemists appear to have made more progress than the foundry chemist, for they have been able to produce from the analysis of ores and mixing of them an iron that when annealed produced malleable iron equal to that of charcoal iron.

Pig iron is now generally graded and sold by analysis, although some furnacemen still adhere to fracture grading, while others grade by analysis and sell by number. New methods of casting and the rapid cooling of pig iron have so completely changed fracture indications in pig iron that foundrymen are practically compelled to adopt the analysis system in ordering and mixing their iron. The analysis for grading and mixing has now attained such a lead in the grading and mixing of foundry irons that it is bound to remain the leading system, and it should be the aim of every foundryman to perfect himself in this method of manipulating his iron.

Chemistry of Pig Iron.

Iron ores are found in combination with almost all of the known elements, many of which are not separated from the iron or destroyed by the heat of a blast furnace in smelting the ore. And in the process of smelting the iron may also take up other elements or impurities from the smelting fuel. So that in pig iron we have the crudest of all the commercial irons. From analysis of ores, chemists have been able to select ores possessing desired properties for steel making, and in foundry practice for malleable iron making, but the foundry chemist has not this broad

field to work from, but he must take the pig iron with all its impurities, in combination with the iron, many of which there is no possibility of eliminating in the cupola melting of iron and produce a metal of a desired quality. This the foundry chemist has been endeavoring to do by increasing the elements or metalloids as they have been termed, that have been found to have a softening effect upon the iron and decreasing the metalloid that has a hardening effect when a soft iron was desired, and for a hard iron, increasing the metalloid that has a hardening effect and decreasing the one that has a softening effect. For a strong iron the metalloid that has been found to be a strengthener is increased, and that having a weakening effect is decreased, and this is the plan and system followed in obtaining fluidity, chilling properties and all the various characteristics desired in iron for the various lines of castings.

All the various elements contained in pig iron have been analyzed but many of them have been found to have such a trifling effect upon the iron, as cast iron, that they are not considered in the manipulation of foundry iron and seldom analyzed for, while others are so seldom found that they are only analyzed for when trouble with the iron is met with and cannot be overcome with this system of elimination. The elements or metalloids considered important in the manipulation of foundry iron have been reduced to four, these are silicon, phosphorus, manganese and sulphur. The functions of these four metalloids in the manipulation of foundry iron are as follows:

Silicon is a softener and strength reducer in iron; phosphorus is a fluidity giver and also a strength reducer; manganese is a hardener, chill increaser, sulphur eliminator and strengthener of iron; sulphur is a hardener and strength reducer.

The various effects of these four metalloids upon iron have been fully demonstrated and proven by chemists in laboratory work, but they cannot be so fully demonstrated or so accurate results obtained in cupola practice where conditions are met with in melting, entirely different from those in laboratory practice, and approximate results can only be attained in foundry irons. That these may be fully obtained the effect of the various metalloids upon iron should be carefully studied by the student.

Silicon.

Silicon is a non-metallic infusible substance which forms the basis of silica, of which quartz rock is an example. It is therefore a foreign body in iron, and may be separated from it as a

white silica sand in laboratory practice, and has also been separated from iron in cupola melting and found in castings.

Silicon combines freely with cast iron, and may be found as high as 20 per cent. in iron smelted from ores heavily impregnated with it, and may be combined with iron up to 95 per cent. in electric and other special furnaces. Above 10 per cent. the iron begins to lose its characteristics as iron, and is difficult to cast, and is termed ferro-silicon.

Silicon promotes the absorption of carbon in cast iron from the melting fuel, and acts upon the iron as a softener by increasing the graphite carbon; as this is increased the crystals of the fracture increase in size until a No. 1 X iron is reached, an increase of silicon beyond this point gradually decreases the size of crystals until the fracture has an appearance very similar to that of a white hard iron but is a soft iron. The point of distinction between these two irons in fracture is the silvery grey color of the soft iron and the white hard iron has a bluish cast of color. A test for these two irons to determine their hardness or softness is to chip or file them. This test should be made by a man accustomed to filing and chipping iron for all iron files or chips hard to a man not accustomed to chipping and filing.

The color of a fresh fracture of a No. 1 X iron varies with the per cent. of other metalloids the iron may contain. That smelted from a southern high silicon ore generally has a light or silver grey cast, and that smelted from a northern ore has a dark or light bluish cast, with the two irons containing the same per cent. of silicon, which in a No. 1 X iron, is about 3.50 per cent.

Silicon also has a weakening effect upon cast iron, which becomes more apparent after it has passed the 3.50 point, and even pig containing about this per cent. has to be handled with care to prevent breaking when unloading from cars. A pig containing about 3 per cent. silicon runs soft and strong in castings of light sections but entirely too open, porous and weak for castings of heavy sections, and pig contains 1.00 to 2.00 per cent. silicon runs hard and weak in castings of light section but soft and strong in castings of heavy sections. These opposite results are not due to the silicon but to the form the carbon has assumed, that is, a combined or graphite state, and the per cent. of silicon in the iron is the indicator of the form it may assume and the degree of hardness or softness that may be found in castings when melting iron containing various per cent. of silicon.

Silicon, when separated from iron by analysis, is in the form of a silica sand, and when present in iron, in a high per cent.

does not harden the iron but imparts to it a grit that grinds the edge off a lathe or planer tool very rapidly, and it can only be turned or planed with the hardest and best of tool steel; this gives the impression that it is a hard iron, which is not the case.

These various effects of silicon upon iron should be carefully studied until fully understood, that this knowledge may be applied in a practical manner in the making of mixtures. The points to be remembered and applied in the making of mixtures are as follows:

First—Silicon is a softener of iron, and a 3.00 per cent. silicon iron is a soft open iron suitable for stove plate bench work and similar light castings. Silicon in mixtures for these lines of castings varies from 2.00 to 3.00 per cent., depending upon the thickness of section.

Second—Silicon is a destroyer of strength in iron, and a 3.00 per cent. silicon iron makes an open, porous, weak iron in heavy castings. For this line of castings a lower silicon should be used. Silicon in mixtures for this line of castings varies from 1.50 to 2.50 per cent. The lower silicon is placed in mixtures for heavy cylinders and other heavy castings designed to be close and strong. 2.50 silicon is placed in castings varying in thickness from one-fourth to one-half inch in thickness. The silicon commonly placed in mixtures for job castings is about 2.00 per cent.

Third—For castings designed to be very hard or very close, 0.50 to 1.50 per cent. silicon is placed in mixtures. The lower per cent. gives a very hard white iron, and the higher per cent. a white iron in light castings and an iron that may be machined in heavy castings but hard and very close.

Fourth—Too high a silicon places a grit in iron that makes it hard to machine, and it is sometimes condemned as a hard iron, but this iron is really a soft iron. The founder should familiarize himself with this phenomena and be able to differentiate between a grit iron and a hard iron. This may be done by a study of the fracture, which in a grit iron is of a light color and silvery grey cast, while that of a hard iron is of a white or light color with a bluish cast. The chipping and filing test above described may also be used. In case a grit is found in the iron the silicon of the mixture should be at once reduced to a point that will remove this grit and make the iron work soft and free.

In all cases where an iron is too hard for the work, the silicon should be increased and when too soft, open, porous and weak, the silicon should be decreased.

Coke iron, when graded by analysis and sold by number, contains about the following per cent. of silicon, which was established by a committee of The American Foundrymen's Association as a standard for iron sold by number:

- No. 1 X iron, 3.50 per cent.
- No. 2 X iron, 3.00 per cent.
- No. 1 plain iron, 2.50 per cent.
- No. 2 plain iron, 2.25 per cent.
- No. 3 mottled iron, 1.50 per cent.
- No. 4 white iron, 1.00 per cent.
- No. 5 white iron, 0.50 per cent.
- Silvery pig iron, 4 to 6 per cent.
- Ferro-silicon iron, 6 to 10 per cent.

The following is the standard for silicon in charcoal iron sold by number:

- No. 1 soft iron, 1.95 per cent.
- No. 2 soft iron, 0.95 per cent.
- No. 3 close iron, 0.55 per cent.
- No. 4 mottled iron, 0.35 per cent.
- No. 5 white iron, 0.22 per cent.

It will be observed that the per cent. of silicon runs much lower in charcoal than in coke iron, but the same results are obtained in mixtures of these irons, the high silicon gives a soft casting and the low silicon a hard casting, and the intermediate grades may be mixed to give an iron of various degrees of hardness and softness.

Silicon Lost in Melting.

It has been determined by a careful analysis of pig, remelt and castings that the loss of silicon in cupola melting is about ten points, or one-tenth of 1 per cent., and this has been set as a standard for loss of silicon in cupola melting.

To ascertain this loss in melting it is necessary that the pig should be accurately analyzed that all remelt, old scrap, etc., placed in the mixture should be analyzed. That the per cent. in each should be accurately figured out and combined in charge

to give the per cent. desired and to attain this, each iron in the charge must be weighed down to odd pounds and total of charges weighed to odd pounds. This method of analysis, weighing charges, etc., would give accurate results in castings, but no one but a chemist fresh from college would think of going into all this detail, for it is not practical to do so with our present system of analysis of foundry iron and cupola practice.

To begin with, the analysis of foundry pig is made by taking drillings from about three pigs selected from different parts of the furnace cast, they are analyzed and the result of this analysis determines the analysis of the entire cast. That this analysis does not accurately indicate the analysis of the entire cast, or the analysis is totally wrong has been proven many times by the iron not producing in castings an iron of the quality indicated by the analysis, and many cars of iron have been condemned and rejected. It is not practical to analyze every piece of old scrap and the analysis of remelt scrap is seldom made, which makes it necessary to adopt a system of averages or guesswork as to the certain contents of a mixture. With this uncertainty to begin with, it is, of course, impossible to determine the loss of silicon in melting.

In the melting of iron in a cupola the iron comes in direct contact with the fuel and blast, in the solid, semi-solid and molten state and a certain per cent. of silicon is burned out of it and there is a correspondent loss of graphite carbon and hardening of the iron. This loss is increased by an excess of fuel in melting, holding the iron above the melting zone where it is roasted and burned until the excess fuel is burned away and permits the iron to settle into the melting zone and the loss of silicon is heavier than if only the proper amount of fuel were charged. When there is a deficiency of fuel, the iron settles so low in the cupola before melting, that it is struck by the blast when in a semi-molten or mushy state and oxidized, and there is an increased loss of silicon and graphite, and also of iron converted into slag. These various conditions make it impossible to state any definite per cent. of silicon lost in melting that would be accurate in all cupolas, even if all iron charged were accurately analyzed.

It is the common practice to estimate the loss of silicon on remelt scrap for charging at one-fourth of 1 per cent. below that in the mixture from which it was melted, and to make the same allowance for loss of silicon in castings. This gives a safe margin to work on, in preventing hardness due to loss of silicon.

Many foundrymen pay no attention to loss of silicon in melting, but establish a standard silicon content of their mixture for various lines or sizes of castings, and vary the per cent. of pig in the mixture to maintain this per cent. of silicon.

Ferro-silicon.

Ferro-silicon is a compound of cast iron and silicon melted or fused together. Silicon is found in combination with iron in its ores, and when the ore is melted, remains in combination with the iron, and a pig iron containing as high as 20 per cent. silicon may be produced by a blast furnace smelting a high silicon ore. This iron when containing from 6 to 10 per cent. silicon is called ferro-silicon pig, and above this point is sometimes termed ferro-silicon. But a real ferro-silicon does not occur to above 20 per cent. silicon, but may run as high as 95 per cent. silicon.

Above 20 per cent. ferro-silicon is made in electric furnaces, the higher per cent. lose all their iron properties, and may be broken into small pieces, crushed into small granules or ground to a powder.

Silicon was found to be a softener of cast iron, to an extent that a white, hard iron could be converted into a soft iron by the introduction of silicon into the melting crucibles used in laboratory practice. It was hoped to produce these same results in cupola practice and ladles of molten iron, and ferro-silicon above 20 per cent. was a product of this discovery for that purpose.

It was heavily advertised for that purpose a few years ago, and there were few foundries that did not give it a trial in both cupola and ladles. The lump or large granular form was designed for use in the cupola, and the powdered form was for use in ladles.

Many tests of this material in the cupola showed that it did not impart to hard iron the softening effect that was claimed for it, this was probably due to the difficulty in bringing it into contact with the molten or semi-molten iron for a sufficient length of time to be absorbed by the iron to an extent that would produce any marked softening effect upon it, and its use for this purpose has been practically abandoned, but no doubt will be taken up again in its present form or perhaps a new form.

Tests in ladles of granular and powdered form only give similar results to that of the cupola, and not sufficient practical

results were obtained in the softening of the iron to warrant a continuation of its use.

Phosphorus.

Phosphorus is a translucent, nearly colorless substance resembling wax, without taste, but having a peculiar smell. It is intensely inflammable and should be kept under water to protect it from light. When exposed to the air it emits white fumes, which are luminous in the dark. It may be obtained in two colors, the white and the red. It does not seem possible that this soft waxy substance that burns in the air without being ignited by heat or flame, should enter into combination with iron, and pass through the heat of a blast furnace and cupola without being entirely consumed, but such is the case.

The white phosphorus in its pure state does not unite with iron, but the red, which contains impurities, enters into combination readily with iron, as does also phosphoric acid, which, to a greater or less extent, is found in all iron ores and cannot be fully eliminated from it in the smelting of the ore.

Phosphorus exists in iron as iron phosphide, which has a lower melting point than iron, and therefore separates from the latter in cooling, forming a network between the crystals. The effect of this separation upon cast iron is to weaken the iron, and to produce in wrought iron what is termed a red short iron. Phosphorus is a detriment in steel and wrought iron in any amount, and every possible means is taken to eliminate it from these metals.

In cast iron, phosphorus acts as a flux upon the molten iron, giving to it life and increased flowing properties, and induces it to run up sharp in the lightest of castings. Without phosphorus in the iron many of the largest pieces of stove plate could not be cast, for many of these plates are so thin that the iron would be chilled by the damp sand of the mould to an extent that would not admit of it filling the mould and making a perfect casting. Phosphorus is therefore classed as the life and fluidity giver of foundry iron.

It is the destroyer of strength in these irons, in the manner explained above, and also increases internal shrinkage in heavy castings by keeping the iron in a molten state for a greater length of time. The per cent. of it in iron must be graded to suit the thickness or weight of casting.

Iron ores are found so highly impregnated with phosphorus that iron may be smelted from them containing as high as 20 per cent. phosphorus, but these are seldom melted alone, as there is no market for such iron. It can also be combined with iron in the electric furnace up to 30 per cent., when it is termed ferro-phosphorus, but iron containing such high per cent. is not used in foundry practice.

The per cent. of phosphorus commonly placed in mixtures for castings varies from 0.20 to 1.00 per cent., and with a very sluggish flowing pig iron or extremely light castings 1.50 per cent. is sometimes used. A good idea of the proper amount to use in the various lines of castings may be gained from our table of analysis of castings. It is a good plan to keep a little high phosphorus pig in stock for the purpose of doctoring sluggish iron.

The apparent effect of phosphorus upon molten iron is to give it the appearance of being a white hot, very fluid iron, and this appearance becomes more marked as the phosphorus is increased.

Manganese.

Manganese is a metal which, when pure, is of a greyish white color, brittle and very hard, being capable of cutting glass. It is susceptible of the most perfect polish, and does not tarnish readily. It is obtained from manganese ores, of which there are a variety, some of which contain as high as 70 per cent. manganese.

It is also found in combination with iron in iron ores, and may be smelted from these ores in a blast furnace and an iron produced containing up to 40 per cent. manganese. This iron is given the name of Spiegel Iron, and is extensively used in steel making.

Manganese is classed as a strengthener, hardener and chill giver in cast iron. This result is effected by decreasing silicon, eliminating graphite carbon and increasing combined carbon. For the purpose of effecting this change and giving a chill of a desired depth, manganese is extensively used by car wheel foundries. For this purpose it is generally charged into the cupola with the iron, and either the metal or its ore are used. The per cent. of manganese or manganese ores required to effect this change depends upon the per cent. of silicon and graphite carbon that it is necessary to eliminate to effect this change. As the

mixture is made as near as possible to give the metal desired the per cent. of manganese used is generally small. The metal may also be used in ladles when only a slight change in the iron is required. To facilitate the rapid melting of the manganese by the molten iron, it is heated to almost the melting point in a forge or furnace before placing in the molten iron. This practice is also followed by many machine and jobbing foundries for special castings requiring strength or chill, and in many cases both strength and chill.

These results are obtained only by the free use of the manganese metal or ore in the cupola or ladle, and they are practically the only results that are obtained from the use of manganese in any form with any degree of certainty in cast iron. The greater affinity of manganese for sulphur than for iron and the uncertainty as to the per cent. of sulphur a semi-molten or molten iron may contain, even after an accurate analysis of the sulphur contents has been made before melting, makes the effect produced by manganese upon iron when placed in molten iron in a ladle very uncertain.

This may be illustrated by the experience of a foundryman at Chicago Heights, Ill., who had a five-ton casting to make that required a certain depth of chill, a very accurate mixture was made for this casting, and to insure it having the desired depth of chill, a certain per cent. of manganese was placed in the iron in the ladle. The casting when cold was found to have the desired chill. A few days later another casting from the same pattern was cast, exactly the same mixture of iron was made and melted with the same quality of coke, the same per cent. of manganese placed in the molten iron in the ladle and the castings when cold had no chill whatever.

This failure of manganese to give a desired chill was attributed to the manganese having combined with sulphur for which it has a great affinity and had not affected the iron at all. But if there was sulphur in the iron, why did the manganese not combine with it and produce no chill in the first casting? And if there was no sulphur in the iron of the first heat, where did it come from in the second heat, when the same iron and fuel were used?

I have met other foundrymen who have had similar experiences, and these are phenomena that no one has yet been able to explain in a way that has prevented them occurring again.

That manganese is an eliminator of silicon was very clearly proven at the plant of the Raleigh Iron Works Co., Raleigh,

N. C., a few years ago. This firm had a U. S. contract for semi-steel projectiles, and to produce them had taken a much advertised course of instructions in the making of manganese semi-steel, which was not at all practical, and I was called upon by this company to locate their troubles. An investigation showed that under this instruction they were using in their mixture a high silicon pig, a high manganese pig, steel scrap and remelt, and charging a manganese ore with each charge of metal. An inspection of the castings when machined showed many of them to contain patches of pure white silica sand, and others of dross or dirt; about 90 per cent. of the castings showed this condition and were condemned. This condition was undoubtedly due to the high manganese and steel separating the silicon from the iron. For when the manganese ore was left out, this condition in the castings improved and when the high manganese pig was reduced and steel increased, a perfect semi-steel casting was made.

Ferro-Manganese.

Ferro-manganese is a compound or alloy of iron and manganese. It is prepared by heat in the electric furnace and may be obtained, containing as high as 90 per cent. manganese. It is prepared for the purpose of treating cast iron and steel.

For the treatment of cast iron it is prepared in three forms, the lump, granular and powdered form. The lump is recommended for use in the cupola, and the granular or powdered for use in the ladle. When used in the cupola the desired per cent. of the lump form is charged with the iron and melted with it; when used in the ladle, the granular or powdered form is used, and may be placed in the ladle before tapping and molten iron tapped upon it, or it may be sprinkled upon the stream as it flows from the cupola and carried into the ladle with the iron. Or placed upon the iron in the ladle and stirred in. All these methods of placing ferro-manganese in the iron have been tried out with no more satisfactory results than when the metal or ore is melted with the iron in the cupola.

In my own experience and tests with manganese in cupola and ladles, I have met with many successes and many failures, and I have no faith whatever in manganese as an eliminator of sulphur and softener of iron, and very much prefer silicon for

this purpose. As a strengthener of iron I have obtained far better results by the use of steel scrap than manganese.

Sulphur.

Sulphur, although classed in chemistry as a metal, has none of the properties of a real metallic metal, but is a hard brittle substance of a yellow color that is easily crushed and reduced to a powder. It may be obtained in two forms, the stick form and the powdered or sublime form, which is commonly known as brimstone.

Sulphur is a very abundant substance in the mineral kingdom, and is found in most all of the metallic ores, and to a greater or less extent in all the mineral fuels. It is found in many of the iron ores, and has a strong affinity for iron, with which it enters into combination freely, and may be taken up from the smelting fuel of the blast furnace or the melting fuel of the cupola.

Sulphur enters into combination with iron in two forms, as an iron sulphide and manganese sulphide. These are fine divisions made in laboratory practice which count for little in cupola practice, as both forms have a hardening and weakening effect upon cast iron, and it is only a difference of the degrees of heat at which they are absorbed or separated from the iron. That sulphur has a decidedly hardening effect and also weakening effect upon iron has long been recognized by foundrymen, and that any benefit that might be derived from the hardening is destroyed by the weakening effect which renders a sulphur hardened iron too weak for castings requiring hardness and strength.

So well founded is the opinion against sulphur in iron, that every precaution is taken to prevent bringing it in contact with foundry irons, and many cars of coke have been condemned for being too high in sulphur, and even cupola and ladle daubing have been condemned as hardeners due to sulphur contained in the clay.

Manganese has been found by chemists to prevent the hardening and weakening effect of sulphur upon cast iron in laboratory practice, but manganese alone is a hardener of cast iron, and combined with sulphur forms manganese sulphide, which is also a hardener of iron. It is only below the point of saturation of both that manganese acts as a destroyer of sulphur and a softener, and the undetermined per cent. of manganese and

sulphur present to form a sulphide, accounts for the softening of iron by manganese in one heat and the production of a chill in another, and as there is no way to determine the per cent. of sulphur the iron has absorbed from the fuel, at the melting point, the exact per cent. of manganese cannot be determined that will destroy sulphur only to the extent of not forming a sulphide and act as a softener, therefore, manganese cannot be depended upon as a softener.

In my own experience in the elimination of sulphur I have found silicon to be far more effective than manganese. While silicon is not classified as an eliminator of sulphur, it is a softener of iron, by increasing graphite carbon, and sulphur is a hardener of iron. An increase of silicon in the mixture increases its softening effect to an extent that offsets the hardening effect of sulphur. I have been able many times to produce a good soft iron in this way when sulphur ran high in the pig and scrap, and also when the hardness was due to high sulphur in the melting coke. I have also advised this method to a number of our students who complained of high sulphur in their coke and in each case they reported satisfactory results.

Sulphur as a Hardener.

A high sulphur pig and selected high sulphur scrap are frequently melted in a cupola for hard castings and in case the iron is not of the desired degree of hardness, stick sulphur is sometimes charged with the coke to add more sulphur to the iron.

This is the very poorest kind of hard iron practice, for a sulphur hardened iron is brittle, inclined to crumble, and does not possess the wearing properties usually required in a hard casting, and the melting of such iron is very destructive to a cupola lining. A founder melting this kind of iron informed me that it was necessary to reline his cupola every heat after melting a seven-ton heat of this iron in a thirty-five-inch cupola. I advised him to melt a low sulphur iron with 50 per cent. steel scrap. This he did and reported a far superior metal for his hard castings than with the high sulphur iron, and the destruction of cupola lining was no greater than when melting a regular mixture of pig and cast scrap.

Another very bad and expensive practice is the hardening of iron by adding sulphur to it in the ladle for a few hard iron castings. A number of failures to make any marked change in the hardness of the iron in this way have been recorded, due to

the failure of the molten iron to absorb the sulphur. In cases where success was recorded it was found that about twelve pounds of sulphur was required for a hundred pounds of iron to change a grey iron into a white iron. The greater part of this large amount of sulphur goes off in fumes, and it is only with very hot iron and constantly stirring the sulphur down into the molten iron that even this amount can be made to change a grey iron into a white iron.

Some years ago, antimony was quite extensively used for the hardening of iron in ladles, but this process proved unreliable, and I have not heard of it being used for this purpose for many years.

The best way I have found of hardening iron in a ladle is to drop light steel turnings into the molten metal, with a close metal to begin with, and very hot iron, a white iron for light castings, or a chill on a heavy casting may be obtained by dropping all the turnings into the hot iron that it will melt and absorb before becoming too dull for pouring. Drop the turnings in from the hand in a way that will not admit of them balling up, and stir them into the molten metal with a hot rod.

The following interesting paper on sulphur in a soft grey iron was read at the Boston, Mass., Convention of the American Foundrymen's Association, September, 1917, and may prove of interest and value to our students.

High Sulphur In Soft Grey Iron

By T. Mauland, Deering Works, International Harvester Co., Chicago

Abstract of Paper.

In spite of the fact that high sulphur is almost universally considered detrimental to good results in the foundry, the author states he has observed that castings up to 0.12 per cent will some-times be the same, the castings will be hard with sulphur less than 0.09 per cent. It may be inferred, therefore, that sulphur is not the determining element in the hardness of grey-iron castings. In his own cupola mixtures the author has found it possible to substitute 20 per cent of off-grade pig iron in place of 10 per cent of No. 1 cast scrap and 10 per cent No. 2 foundry pig without detrimental results. Analyses of a lot of test castings ranging from 0.143 to 0.170 per cent. sulphur are presented and it is stated that in every case the castings machined soft. The author concludes that sulphur in itself is not nearly so bad as it has been painted. He also believes the reason good cast-

ings sometimes are obtained with high sulphur iron lies in the fact that the oxygen in such cases usually is low.

Sulphur is considered cast iron's worst enemy, and many of the troubles of the foundry are laid to it whenever it happens to be high. Authorities say that sulphur combines carbon, increases hardness, shrinkage and chill; reduces strength; causes dirty iron, blow holes and shrinkage cracks; and makes iron congeal quickly. Generally this is true, but my experience has been that sulphur within certain limits increases strength in soft iron. For agricultural or similar classes of castings, specifications have called for a maximum sulphur of 0.08 or 0.09 per cent. The American Society for Testing Materials, I understand, is considering increasing this limit to 0.10 per cent.

In castings of this class, sulphur is generally used as an indication of the hardness. I have noticed, however, that castings with a higher sulphur, up to 0.12 per cent. will sometimes be good, strong and soft, while at other times, with the other elements the same, the castings will be hard with sulphur less than 0.09 per cent. It has been my experience that when using a mixture of, say, 55 per cent pig, 35 per cent home scrap and 10 per cent No. 1 cast scrap, and it became desirable on account of economy to substitute 0.12 to 0.15 per cent sulphur off-grade pig iron for the No. 1 cast scrap, I could use a mixture of 45 per cent pig iron, 35 per cent home scrap and 20 per cent off-grade pig. In other words, I would use 20 per cent off-grade pig in place of 10 per cent No. 1 cast scrap, although the average sulphur analysis of the scrap would be better than the off-grade pig. The analysis of the castings from the off-grade pig mixture would be the same, excepting it would show a higher sulphur. But the iron would be just as good and just as soft as the lower sulphur iron made from the scrap mixture.

A Bad Reputation

In steel, sulphur has had the same bad reputation that it has in the foundry. Bessemer steel specifications generally call for 0.08 per cent or less, and open-hearth specifications for 0.05 per cent or less, as the maximum sulphur limit. Dr. J. S. Unger, of the United States Steel Corporation, has made some extensive tests with high sulphur in open-hearth steel. These tests, which were made with varying sulphur contents from 0.03 to 0.25 per cent, showed that good steel could be made with the higher sulphur. High-sulphur steel was made into rivets, chain, sheets, wire, tubes, pipes, forgings, wire rope, rails, etc.

These tests showed that high-sulphur steel could be made with mechanical and working properties equal to that of low-sulphur steel.

Dr. J. E. Stead, the eminent English metallurgist, in a paper before the British Iron and Steel Institute, cites experiments with steel containing from 0.10 to 0.50 per cent. sulphur with as good, or superior mechanical properties, as steel of lower sulphur. The following extracts are taken from his paper:

"It was proved long ago that manganese counteracted the effect of sulphur, but books have been written in which sulphur was condemned, and engineers and their experts read those books and copied them, so that even to this day steel rails, etc., of exceptional quality are rejected because the sulphur exceeds arbitrary limits, even when all mechanical tests proved that material is perfect. Steel high in sulphur resembles wrought iron and is more or less fibrous. It is a fact that steel called free-cutting fibrous steel is used today and the peculiar properties referred to are due to the deliberate introduction of sulphur into the steel. Such material contains about 0.15 per cent sulphur. Sulphur, then, may be regarded as a friend when it is used intelligently and is not invariably the enemy it is represented to be."

Some High-Sulphur Iron Soft

Within the last few months I have run into some rather extraordinary cases of high sulphur iron showing up very soft. The casting used as a test piece was a small grey iron box or bushing $2\frac{1}{2}$ inches long with a $\frac{3}{4}$ -inch core. The lighter portion, including the upper end, is 3-16-inch thick. The heavier portion is $\frac{1}{4}$ -inch thick. The $\frac{3}{4}$ -inch cored hole is reamed to a 0.890-inch hole on a gang drill. This machining is done with a feed of $4\frac{1}{4}$ inches per minute. This casting is one that is very apt to cause trouble in machining on account of a hard upper edge in the lighter section. Ordinarily, it is not safe to run this iron over 0.10 per cent in sulphur, and this casting has given trouble with sulphur as low as 0.08 per cent. In the cases just mentioned, where the iron was satisfactorily soft, the analyses were as follows:

Lot No.	Sulphur Per cent	Silicon Per cent	Manganese Per cent	Phosphorus Per cent	Total Carbon Per cent
1.....	0.156	2.11	0.44	0.70	3.39
2.....	0.143	2.12	0.44	0.70	3.47
3.....	0.145	1.93	0.46	0.40	....
4.....	0.170	2.09	0.44	0.40	....

The casting, the small box previously referred to, machined soft from all of the four lots.

The high sulphur in lots Nos. 1 and 2 was obtained accidentally. I had already tested the castings for softness, and was very much surprised that analysis showed such high sulphur. The high sulphur in lots Nos. 3 and 4 was obtained by using high-sulphur pig and adding sulphur to the molten metal.

Not So Bad As Painted

The cases of good iron with high sulphur and many cases of poor iron of practically the same analysis but lower sulphur, lead me to believe that sulphur in itself is not nearly so bad as it has been painted. Where sulphur is blamed for poor iron, I do not say that this iron would not have been better had it been lower in sulphur, but I believe that in most cases iron higher in sulphur could be made that would give satisfactory castings.

At this time I will not try to explain why some high-sulphur iron makes very good castings, but I am inclined to believe that oxygen, as described in papers written by J. E. Johnson, Jr., one of which was read before this association several years ago, has much to do with it. The oxygen in the four lots cited above was very low, but I have not had the opportunity to do enough work along this line to draw definite conclusions.

I intend to make some more experiments with even higher sulphur, but time will not permit the results to be included in this paper. All sulphur determinations mentioned have been checked by at least one other laboratory besides our own.

Foundry Foreman As a Chemist

We receive many letters from foundry foremen inquiring if we teach foundry chemistry or give instructions in the making of analysis of foundry irons. We do not give such a course, for chemistry is a science that is separate and distinct from foundry practice and for which a foreman has no use as a money maker, and is too expensive as an accomplishment for a workman, for the following reasons:

A four-year course of study is required by the various colleges and technical schools to graduate a student in chemistry. And if he is not bright and able to pass his examination one or more years may be required.

Chemistry has a language or terms of its own that are not understood by a man without a technical education, and to take

a text-book on chemistry and learn the meaning of the various chemical terms from a chemical dictionary is an endless task. After these terms have been learned, it is a very slow and tedious undertaking to learn the mode of making analysis from books alone. Very few who undertake the study of chemistry, in this way, make a success of it. And probably not more than one foundry foreman in a hundred would follow it up to a success. To employ an instructor for instructions in analysis of foundry irons alone would cost from twenty-five to a hundred dollars and require considerable time, which cannot always be spent at laboratories in the evening, as such instructions are generally given in laboratories where only day work is done. After the student has completed his course and is competent to make analysis he must have a laboratory before he can do the work. To fit up a laboratory, with the present war prices, would cost five hundred dollars, and the average price of each determination, which has been estimated at one dollar and twenty-five cents, would probably cost two dollars. To fit up a laboratory in a home, where there are children, a special room that can be securely locked is required, for all the acids and chemicals used in analysis are either poisonous or injurious to the skin, and much of the apparatus is glass and easily broken, which makes a laboratory not a very desirable place to have children play in. For all this outlay, there is not one dollar of return, for a foreman, as a rule, that can make analysis is paid no more salary than one who cannot. For he can only make such analysis at the foundry, by neglecting his other duties as a foreman, and on his regular time. If he makes analysis at his home, this is regarded as part of his duty, in locating foundry troubles and overcoming them, and is seldom paid for, and even if paid for at a fair price for each determination, the average foundry has not a sufficient amount of this work to pay for keeping up a laboratory. For mechanical analysis or tests answer every purpose in keeping iron up to the standard, and it is only when this fails that analysis is resorted to to locate the trouble.

All the knowledge of chemistry a foreman requires is a knowledge of the four metalloids analyzed for by furnacemen and furnished with each car of pig and their effects upon the iron. This enables him to manipulate his irons, for the production of an iron of a desired quality, as accurately as a chemist can do, and it is only when this fails that an analysis is required to determine if the blast furnace analysis is correct, and, if so, what other metalloid in the iron is causing the trouble. This can be done at a less cost by a testing laboratory than a foundryman or foreman can maintain a laboratory to do it.

Mixing Iron by Analysis

CHAPTER V.

Before attempting to mix iron by analysis, it is necessary to learn and fully understand the effect of the four important elements or metalloids upon the iron. These are silicon, phosphorus, manganese and sulphur.

Silicon is a softener and strengthener of cast iron, up to a certain point which is determined by the thickness, size and shape of casting. For stove plate and light bench work castings, a high silicon gives a soft, strong iron. Silicon 2.50 to 3.00 is commonly placed in mixtures for these lines of castings, which, with very few exceptions, are the lightest of cast iron castings. Analysis of these castings has shown that castings contain from 2.25 to 2.50 sil. are the strongest and softest castings. Below these points they are liable to be hard and brittle. The higher silicon stated above is placed in mixtures for melting and is designed to cover error in analysis and excessive loss in melting and insure this per cent in the castings. In case the castings are found to be running hard, due to error in analysis of pig, or to sulphur in coke, the silicon should at once be increased in a mixture to a point that will insure soft castings. This may be done by increasing the per cent. of the highest silicon pig in the mixture, or by placing in the mixture a small per cent. of pig containing from 4.00 to 5.00 per cent. silicon.

The above mixture will be found suitable for light rimmed pulleys and any casting running out to a thin edge, but is too open and weak for heavy castings. For heavier castings a lower silicon is required, and in mixtures it is graded from 2.50 to as low as 0.50. The latter for a white, very hard iron. For

light jobbing castings, 2.00 per cent is generally placed in mixtures, and if there are sufficient, very light castings requiring a very soft iron, one or more charges may be made on the bed or in the first part of the heat, of 2.25 to 2.50 sil., and for a limited amount of close or hard iron, one or more low silicon charges are placed in the latter part of the heat. When melting soft and close or hard irons in the same heat, it is the practice to charge the soft iron first, and if there is any unimportant or common castings to pour them between the soft and hard iron. This is done to prevent soft iron getting into the hard castings and hard iron getting into the soft ones. If there is no common work to be cast, and all the castings are to be either soft or hard, the practice is to place sufficient extra coke between the soft and hard iron to retard the melting of the hard iron, until all the soft iron can be drawn from the cupola. This insures a separation of the irons and prevents mixing of the soft and hard to any extent that destroys the castings either way.

An excess of silicon reduces the fluidity of molten iron, reduces the strength of the iron, and places a grit into it that makes it difficult to machine; about 3.00 per cent is the limit for a good soft casting.

As high as 12 per cent silicon iron is being cast for special purposes. These castings are very weak and have to be handled as carefully as glass to avoid breaking them. These castings are classed as acid-resisting castings.

The per cent of silicon generally placed in the various lines of castings may be learned from our table of analysis of castings, which gives the high and low per cent that was found by analysis of many castings cast at different foundries. The wide difference between the high and low for some castings is due to some parties requiring a softer iron than others in the same type of castings, and also, in some cases, to undetermined metaloids in the iron, causing it to run harder or softer than other irons containing the same per cent of silicon.

In melting old cast promiscuous scrap, it is generally figured in mixtures at 1.75 sil., and selected scrap is figured at what analysis of castings states such castings contain, which varies from 0.50 to 2.50 sil., and in making mixtures a sufficiently high per cent of silicon is added in the pig to bring the total silicon in the mixture up to the point desired in castings, after allowing for loss of silicon in melting. When a harder iron is desired than that indicated by the silicon in the scrap, a lower silicon pig is used to bring the silicon of the mixture down to the per cent

desired. By varying the per cent of silicon in a mixture in this way, through the pig, as good castings can be made from scrap as with all pig. By the use of a high silicon pig, as high as 75 per cent scrap may be melted for soft castings.

Manganese is classed as a strengthener, softener, hardener and chill-increaser of cast iron, and it also has a chilling or dulling effect upon molten iron in a ladle, giving to it a yellowish or dull red appearance and reducing its fluidity and flowing properties. These many properties attributed to manganese make it the most uncertain metalloid the founder has to deal with, for it may fail to produce any one of these effects when desired and produce them when not desired.

This uncertainty of the effect of manganese in cast iron is due to the action of other metalloids in the iron, upon the manganese and iron, and it is only by getting these in a proper proportion to the manganese that the desired effect upon an iron can be obtained.

Silicon has a powerful control over manganese as a hardener and chill producer, without affecting its strengthening effect, when in proper proportions. This is illustrated in the average mixture made for stove plate and chilled car wheels, which are as follows: Stove plate, Sil. 2.25-2.75; Phos. 0.60-0.90; Mang. .60-.80. Car wheels, Sil. 0.60-0.70; Phos. .30-.40; Mang. .30-.40. It will be observed that the manganese is twice as high in the stove plate mixture, required to be soft and strong, as in the car wheel mixture, required to be strong with a deep chill. This would seem to indicate that manganese was a softener rather than a hardener and chill giver; but it will be observed that silicon in the stove plate mixture is almost four times as high as in the car wheel mixture, which prevents its hardening effect upon the iron, while retaining the strengthening effect in these thin castings. Were these two mixtures to be reversed, the stove plate mixture poured for car wheels, scarcely a perceptible chill would be found on the chilled tread of the wheels, and the car wheel mixture would give a white, hard, easily broken stove plate that could not be used at all. The above stove plate mixture gives an excellent iron for this plate and other very light castings, but would be entirely too open, soft and weak for heavy castings. For such castings the silicon should be reduced to a point that will give an iron of the desired softness for machining and possessing maximum strength. This result may be obtained for many castings by both a lower manganese and lower silicon in the same mixture.

Phosphorus is classed as a fluidity giver or increaser in cast iron. It will be observed that in the above mixture there is a wide difference in the per cent of phosphorus they contain. This is due to the stove plate requiring a more fluid and longer-lived iron to cast the large, thin plates of stove plate than is required to cast the thick web, heavy tread and hub of a car wheel, and also to the fact that a low phosphorus iron changes from a liquid to a solid form quickly, gives a deeper chill than a high phosphorus, one which retains its fluidity for a longer time.

Carbon is the true fluidity giver and the maker of cast iron, for an iron entirely free from carbon cannot be cast, except at a temperature far above the casting temperature of steel, and even then, it cannot be cast into thin plates in a mould and a perfect casting produced. Graphite carbon gives a more fluid and longer-lived iron than combined carbon, and, therefore, a high silicon iron holds its fluidity longer and flows more freely than a low silicon iron.

Phosphorus, although classed as a fluidity giver, is only an adjunct to carbon as a fluidity giver, and is only considered of importance in mixtures for very light castings. Very few of the foundry pig iron contain a sufficiently high phosphorus to injure the strength of the iron, and little attention is paid to it in mixtures, except for special castings, which may be learned from our analysis of castings. 1.00 per cent phosphorus is about the high limit for light castings, and 0.10 the low for special castings. For general run of castings 0.20 to 0.40 per cent.

Sulphur is a hardener and reducer of strength in cast iron and an undesirable metalloid in a foundry iron for any casting. Practically none of the foundry pig irons contain sufficient sulphur to be objectionable in castings, but cupola melted iron takes up sulphur from a high sulphur coke in melting. This sulphur hardens the iron to an extent that frequently makes it unsuitable for work to be cast. Manganese is recommended as a preventative of this hardening of the iron, but manganese is also a hardener of iron, and it has not been found practical in cupola melting to define accurately the exact per cent of manganese that will prevent sulphur hardening and not cause manganese hardening, and as one hardening is as objectionable in castings to be machined as the other, the use of manganese as a preventative of hardness due to high sulphur coke has been almost entirely abandoned. Silicon is not an eliminator of sulphur, but it is a softener and offsets the hardening effect of sulphur, and by increasing the

silicon in a mixture I have been able, many times, to melt iron with coke containing more than 1 per cent sulphur and produce good soft castings, even for stove plates, and I would advise an increase of silicon rather than of manganese as a preventative of hardness due to a high sulphur coke.

TABULATION OF MATERIAL TO BE CHARGED AND METHOD OF FIGURING THE MIXTURE.

Kind of Metal.	Weight Lbs.	Analysis.				Weight in Charge.			
		Sil., Per Cent.	Sul., Per Cent.	Phos. Per Cent.	Mang. Per Cent.	Sil., Per Cent.	Sul., Per Cent.	Phos. Per Cent.	Mang. Per Cent.
Steel Scrap.....	.400	0.10	0.07	0.10	0.60	0.40	0.28	0.40	2.40
Machinery Scrap....	2.000	1.70	0.10	1.00	0.60	34.00	2.00	20.00	12.00
High Sul. Suth.....	1.600	0.70	0.10	1.50	0.30	11.20	1.90	24.00	4.80
No. 1 X.....	1.600	3.00	0.03	0.80	1.25	48.00	0.48	12.80	20.00
No. 2 Foundry.....	4.000	1.75	0.07	0.30	0.60	70.00	2.80	12.00	24.00
High Sil. Iron.....	.800	3.50	0.025	0.07	0.60	28.00	0.20	0.56	4.80
Total	10.400	.....	.....	.....	.....	191.60	7.36	69.76	68.00
Average Per Cent. in Charge.....	.....	.....	.....	.....	.....	1.84	0.071	0.67	0.65

The above table shows the method of figuring mixtures by analysis and the system of keeping a record of mixtures in charge and heat for reference.

Under analysis is placed the known per cent of various elements in one hundred pounds of iron. The weight in charge is a multiple of this per cent: thus, steel scrap, Si 0.10 in 100 lbs. of scrap. 400 lbs. gives weight of elements in the charge. $4 \times 10 = .40$. The per cent in each kind of metal is carried out in this way and the total of each element in charge is divided by weight of metal in the charge. To the total weight of elements is added two ciphers before dividing; this gives per cent and fraction of per cent; three ciphers added gives thousandths of per cent. Thus, sul. 7.36, add three ciphers, 7360000, and divide by total weight of metal in charge: $10400 \div 736000 = 0.071$. The small fraction remaining after dividing for hundredths or thousandths is not considered of importance and the whole number nearest the figure is taken as result, which in this case is 0.071 or 0.07 per cent.

The per cents of element in scrap are estimated from shape of scrap, which indicates the line of casting to which they belong; and analysis of castings gives the per cent in this line of castings,

allowance being made for loss in melting. Analyses of pig are made from a few pigs, taken from a carload, and only represent approximately the per cent of the various elements in the entire carload of iron. It is, therefore, not necessary, or the practice, to figure on small fractions or to place odd pounds in the charges. 50 to 100 pounds is the rule in making charges.

Special Pig

In making mixtures by analysis the best results are obtained by having desired metalloids in the pig, in place of melting ferro-alloy ores or metals in the cupola with the iron, or melting them in ladles of molten iron to have them absorbed by the iron. For the metalloids in the pig are already alloyed with the iron, and when melted with an iron deficient in a desired metalloid mixes with it in melting and imparts to the entire mixture the effect of the desired metalloid upon the iron.

It is the practice of foundries making special lines of castings to order iron containing the per cent of the various metalloids that has proven satisfactory for their line of castings and to carry in the yard a few tons of special pig containing an excess or deficiency of the most important or controlling metalloid in their mixture. As a softener a 3.00 to 5.00 per cent silicon pig is carried, and in case the regular pig is a little below the standard, or coke a little high in sulphur, and castings too hard, a sufficient per cent of this pig is placed in the mixture to increase the silicon of the mixture and bring the iron up to the standard of softness.

Foundries making hard castings carry a 0.50 to 1.00 silicon placed in the mixtures to decrease the silicon and increase hardness or closeness of the iron.

As a fluidity increaser, a 1.00 to 2.00 per cent phosphorus pig is carried by foundries making very light castings, to make up any deficiency of phosphorus in the mixture and increase fluidity in the molten iron.

A high manganese pig is also carried by foundries making close, strong, hard or chilled castings, to close up and strengthen iron for special castings, give increased hardness or increased depth of chill when the mixture is not up to the standard.

Pig containing these excessive high or low metalloids are seldom used in regular mixtures, as a pig iron containing as near as possible the required metalloid in castings gives a more even iron in the casting. But when used in mixtures containing

near the per cent in the special pig this unevenness is not noticed if the pig is broken small and evenly distributed in charging.

With these high metalloids pigs an iron of any desired quality may be made with a mixture of pig or scrap if the iron is tapped into a large mixing ladle or one charge may be melted for special castings. A good idea of the per cent of the various metalloids that have given the best results in the various lines of castings may be gained from our analysis of castings. The high and low found in the analysis of many castings from different irons are due to undetermined elements in the iron, which makes it necessary to place certain metalloids higher in one iron than in others, and a good plan is to use a per cent between the high and low to begin with, and vary it to suit the iron in the casting.

Chemical Standard for Iron Castings

Silicon, Per Cent.	Sulphur, Per Cent.	Phos., Per Cent.	Mang., Per Cent.
<i>Acid Resisting Castings</i>			
1.00—2.00	und .05	und .40	1.00—1.50
<i>Agricultural Machinery, Ordinary</i>			
2.90—2.50	.06—.08	.60—.80	.60— .80
<i>Agricultural Machinery, Very Thin</i>			
2.25—2.75	.06—.08	.70—.90	.50— .70
<i>Air Cylinders</i>			
1.00—1.75	und .09	.30—.50	.70— .90
<i>Ammonia Cylinders</i>			
1.00—1.75	und .09	.30—.50	.70— .90
<i>Annealing Boxes for Malleable Casting Work</i>			
.65	.05	.10—.20	.20
<i>Annealing Boxes, Pots and Pans</i>			
1.40—1.60	und .06	und .20	.60—1.00
<i>Automobile Castings</i>			
1.75—2.25	und .08	.40—.50	.60— .80
<i>Automobile Cylinders</i>			
1.75—2.00	und .08	.40—.50	.60— .80

	Silicon, Per Cent.	Sulphur, Per Cent.	Phos., Per Cent.	Mang., Per Cent.
<i>Automobile Flywheels</i>				
2.25—2.50		und .07	.40—.50	.50—.70
<i>Balls for Ball Mills</i>				
1.00—1.25		und .08	und .20	.60—1.00
<i>Bed Plates</i>				
1.25—1.75		und .10	.30—.50	.60—.80
<i>Boiler Castings</i>				
2.00—2.50		und .06	und .20	.60—100
<i>Brake Shoes</i>				
1.40—1.60		.08—.10	.30	.50—.70
<i>Car Castings, Grey Iron</i>				
1.50—2.25		und .08	.40—.60	.60—.80
<i>Car Wheels, Chilled</i>				
.60—.70		.08—.10	.30—.40	.50—.60
<i>Chilled Castings</i>				
.75—1.25		.08—.10	.20—.40	.80—1.00
<i>Chills</i>				
1.75—2.25		und .07	.20—.40	.60—1.00
<i>Collars and Couplings for Shafting</i>				
1.75—2.00		und .08	.40—.50	.60—.80
<i>Cotton Machinery</i>				
2.00—2.25		und .08	.60—.80	.60—.80
<i>Crusher Jaws</i>				
.80—1.00		.08—.10	.20—.40	.80—1.00
<i>Cutting Tools, Chilled Cast Iron</i>				
1.00—1.25		und .08	.20—.40	.60—.80
<i>Dies for Drop Hammers</i>				
1.25—1.50		und .07	und .20	.60—.80
<i>Diamond Polishing Wheels</i>				
2.70		und .06	.30	.44

	Silicon, Per Cent.	Sulphur, Per Cent.	Phos., Per Cent.	Mang., Per Cent.
<i>Dynamos and Motor Frames, Bases and Spiders, Large</i>				
2.00—2.50		und .08	.50—.80	.30— .40
<i>Dynamos and Motor Frames, Bases and Spiders, Small</i>				
1.50—3.00		und .08	.50—.80	.30— .40
<i>Electrical Castings</i>				
2.00—3.00		und .08	.50—.80	.30— .40
<i>Engine Frames</i>				
1.25—2.00		und .09	.30—.50	.60—1.00
<i>Farm Implements</i>				
2.00—2.50		.06—.08	.50—.80	.60— .80
<i>Fire Pots</i>				
2.00—2.50		.06	.20	.60—1.00
<i>Fly Wheels, Small</i>				
1.50—2.25		.08	.40—.60	.50— .70
<i>Friction Clutches</i>				
1.75—2.00		.08—.10	und .30	.50— .70
<i>Furnace Castings</i>				
2.00—2.50		.06	und .20	.60—1.00
<i>Gas Engine Cylinders</i>				
1.00—1.75		.08	.20—.40	.70— .90
<i>Gears, Heavy</i>				
1.00—1.50		.08—.10	.30—.50	.80—1.00
<i>Gears, Medium</i>				
1.50—2.00		.09	.40—.60	.70— .90
<i>Gears, Small</i>				
2.00—2.50		.06	.50—.70	.60— .80
<i>Grate Bars</i>				
2.00—2.50		.06	.20	.60—1.00
<i>Grinding Machinery, Chilled Castings</i>				
.50— .75		.02	.45	1.50—2.00

Silicon, Per Cent.	Sulphur, Per Cent.	Phos., Per Cent.	Mang., Per Cent.
<i>Gun Carriages</i>			
1.00—1.25	.06	.20—.30	.80—1.00
<i>Gun Iron</i>			
1.00—1.25	.06	.20—.30	.80—1.25
<i>Hangers for Shafting</i>			
1.00—2.00	.08	.40—.50	.60—.80
<i>Hardware Light</i>			
2.25—2.75	.08	.50—.80	.50—.70
<i>Heat Resisting Iron</i>			
1.25—2.50	.06	.10—.20	.60—1.00
<i>Hollow Ware</i>			
2.25—2.75	.08	.50—.70	.50—.70
<i>Housing for Rolling Mills</i>			
1.00—1.25	.08	.20—.30	.80—1.00
<i>Hydraulic Cylinders, Heavy</i>			
.80—1.20	.10	.20—.40	.80—1.00
<i>Hydraulic Cylinders, Medium</i>			
1.20—1.60	.09	.30—.50	.70—.90
<i>Ingot Molds and Stools</i>			
1.25—1.50	.06	.10—.20	.60—1.00
<i>Locomotive Castings, Heavy</i>			
1.25—1.50	.08	.30—.50	.70—.90
<i>Locomotive Castings, Light</i>			
1.50—2.00	.08	.40—.60	.60—.80
<i>Locomotive Cylinders</i>			
1.00—1.50	.08—.10	.30—.50	.80—1.00
<i>Machinery Castings, Heavy</i>			
1.00—1.50	.10	.30—.50	.80—1.00
<i>Machinery Castings, Medium</i>			
1.50—2.00	.09	.40—.60	.60—.80

	Silicon, Per Cent.	Sulphur, Per Cent.	Phos., Per Cent.	Mang., Per Cent.
<i>Machinery Castings, Light</i>				
2.00—2.50		.08	.50— .70	.50— .70
<i>Ornamental Work</i>				
2.25—2.75		.08	.60—1.00	.50— .70
<i>Permanent Mold Castings</i>				
1.50—3.00		.06	.20— .40	.30— .40
<i>Permanent Molds</i>				
2.00—2.25		.07	.20— .40	.60—1.00
<i>Piano Plates</i>				
2.00—2.25		.07	.40— .60	.60— .80
<i>Pillow Blocks</i>				
1.50—1.75		.08	.40— .50	.60— .80
<i>Pipe</i>				
1.50—2.00		.10	.50— .80	.60— .80
<i>Pipe Fittings</i>				
1.75—2.50		.08	.50— .80	.60— .80
<i>Pipe Fittings for Superheated Steam Lines</i>				
1.50—1.75		.08	.20— .40	.70— .90
<i>Piston Rings</i>				
1.75—2.00		.08	.30— .50	.40— .60
<i>Plow Points, Chilled</i>				
.75—1.25		.08	.20— .30	.80—1.00
<i>Propeller Wheels</i>				
1.00—1.75		.10	.20— .40	.60—1.00
<i>Pulleys, Heavy</i>				
1.75—2.25		.09	.50— .70	.60— .80
<i>Pulleys, Light</i>				
2.25—2.75		.08	.60— .80	.50— .70
<i>Pumps, Hand</i>				
2.00—2.25		.08	.60— .80	.50— .70

Silicon, Per Cent.	Sulphur, Per Cent.	Phos., Per Cent.	Mang., Per Cent.
<i>Radiators</i>			
2.00—2.25	.08	.60— .80	.50— .70
<i>Railroad Castings</i>			
1.50—2.25	.08	.40— .60	.60— .80
<i>Rolls, Chilled</i>			
.60— .80	.06	.20— .40	1.00—1.20
<i>Rolls, Unchilled</i>			
.75	.03	.25	.66
<i>Scales</i>			
2.00—2.30	.08	.60—1.00	.50— .70
<i>Slag Car Castings</i>			
1.75—2.00	.07	.20— .30	.70— .90
<i>Soil Pipe and Fittings</i>			
1.75—2.25	.09	.50— .80	.60— .80
<i>Steam Cylinders, Heavy</i>			
1.00—1.25	.10	.20— .40	.80—1.00
<i>Steam Cylinders, Medium</i>			
1.50—1.80	.07	.30— .50	.70— .90
<i>Stove Plate</i>			
2.25—2.75	.08	.60— .90	.60— .80
<i>Valves, Large</i>			
1.25—1.75	.09	.20— .40	.80—1.00
<i>Valves, Small</i>			
1.75—2.25	.08	.30— .50	.60— .80
<i>Water Heaters</i>			
2.00—2.25	.08	.30— .50	.60— .80
<i>Wheels, Large</i>			
1.50—2.25	.08	.30— .40	.60— .80
<i>Wheels, Small</i>			
1.75—2.00	.09	.40— .50	.50— .70
<i>White Iron Castings</i>			
.50— .90	.15	.20— .70	.20— .50

The above standard for analysis of iron castings represents the analysis suggested by a committee appointed by The American Foundrymen's Association to establish a standard chemical analysis for iron castings. To establish this standard, drillings were taken from about three hundred and fifty separate castings made at foundries located in different sections of the country, and melting iron made in their sections. These samples, for the same lines of castings, differed so widely in analysis that it was found impossible to state an analysis that would apply to all the various castings and iron from which the samples were taken, and the best they could do was to take an average of the high and low metalloids found by the analysis and suggest this for a standard. But this can only be regarded as points between which to work in finding analysis that gives the best results with iron melted.

Stove Plate Mixture.

A mixture of iron for stove plate is made of No. 1 and No. 2 plain, or X irons. No. 3 or the lower grades are never placed in this mixture, and old cast scrap is seldom placed in the mixture. It is said to be a poor foundry that cannot make its own scrap, and the stove foundries come fully up to the standard of a good foundry in this respect, for their remelt of gates, discount and broken castings frequently exceeds 50 per cent. of the heat, and seldom runs below 40 per cent.

The No. 1 pig is the high silicon iron, and is regarded as the softener, and No. 2, the lower silicon iron, the strengthener. In case the plate is a little hard, or the per cent. of remelt unusually heavy, the per cent. of No. 1 in the mixture is increased as a softener, and No. 2 decreased. In case the iron is very soft, but weak, No. 2 is increased, as a strengthener, and No. 1 decreased. The changes to be made are determined every day by tests of strength, hardness, and shrinkage of the iron. Shrinkage in castings, to be assembled, is a very important matter; this is increased by low silicon and decreased by high silicon; the per cent. of shrinkage in these castings is of little importance so long as it remains the same from day to day.

The iron from one furnace may be used for this mixture, but it is generally considered that a mixture of iron from furnaces smelting different mixtures of ores makes a better casting than the iron of one furnace, and it is the general practice to place two or three brands of iron in the mixture, and I have seen as high as seventeen brands and grades placed in a mixture.

In ordering irons, it is the practice to specify the analysis desired and to have the silicon of one brand run a little higher than required, to be used as a softener; the phosphorus in another run high, to be used as a fluidity increaser, and the manganese of another run high as a strengthener. This enables the founder to vary them in a mixture to give an iron of a desired quality, without making a radical change of mixture by using a special pig, and gives a more even iron in the casting.

Five per cent. steel scrap has been found to increase the strength of this mixture to the extent of five hundred pounds to the square inch, and greatly reduce breakage in tumbling and mounting, and it is now the practice of stove founders to melt in their mixture all of their mounting house steel scrap. To do this it is only necessary to increase the silicon to an extent that will carry the steel scrap without hardening.

Testing Pig Iron.

The analysis of foundry pig is generally supposed to fully indicate the characteristics of the iron when cast, but this has been proven many times not to be correct, and tons of castings have been lost by depending entirely upon analysis. The reasons for this are:

First—The analysis is made from drillings taken from a few pigs in a furnace cast or from a carload of pig, and even when the analysis is perfectly accurate may not fairly represent the analysis of the entire cast, or carload. This has frequently occurred and caused the loss of many castings.

Second—Only the four metalloids, silicon, sulphur, phosphorous and manganese are analyzed for, except when special analysis is made, and the known effect of one or more of these metalloids upon the iron when remelted may be entirely changed by the presence of unknown metalloid in the iron that has not been analyzed for. This has been found by further analysis to have been the cause of loss of castings in a number of instances.

Third—An iron may show a proper analysis of the four metalloids and be a good iron for the work to be cast, whether soft or hard, when melted alone, but when melted in a mixture with other pig proved to be the worst of iron, or what is commonly termed a hoodoo iron. This is due to the undetermined metalloids in the iron, being in proportion with the other four metalloids to produce an iron of a desired quality, but when melted with other irons in a mixture, the undetermined metal-

loid throws the other metalloids out of proportion and an entirely different iron is produced. This was found to be the case at a foundry in East Cambridge, Mass., a few years ago, when a new iron was placed in the mixture for machined castings, and the castings found to be so hard that not one of them could be machined.

This founder was melting three different brands of pig in their mixture; it was desired to replace one of these brands with one from another furnace that was highly recommended. Before placing this iron in the mixture, it was carefully analyzed by the foundry chemist, and found to contain the desired per cent. of the four metalloids for soft machine castings, and it was placed in the mixture in the same per cent. as the iron that it replaced, with the result that the entire heat of castings was too hard for machining and had to be scrapped. A further analysis of this pig showed that it contained titanium, which was not a hardener in combination with the per cent. of the four metalloids of the pig, but, when melted with the other two pigs, one or both of which may have contained a higher per cent. of one or more metalloids with which the titanium entered into combination, to produce a hard iron. The metalloid that produced this effect when combined with the titanium was probably manganese, but I am not aware that this was fully determined.

This serves to illustrate the uncertainty of results from analysis when only four metalloids are analyzed for, and to prevent heavy loss of casting, all new brands or cars of pig should be carefully tested before placed in the mixture for an entire heat.

Testing may be done by placing 5 or 10 per cent. of it in the mixture and noticing the results, and increasing the per cent. each heat until the desired per cent. is placed in the mixture, or it may be tested by placing the full per cent. in the mixture for one charge and pouring this charge into an unimportant casting.

Hoodoo Pig Iron.

An apparently soft, even pig iron, in the fresh fracture, or indicated soft iron by analysis, that will not run soft, even, or strong when melted with other pig, remelt or scrap, is frequently condemned as a hoodoo iron and returned to the furnace, sold at a loss, or piled in the foundry yard, where it may remain for many years to rust and depreciate in value.

In visiting foundries I have found many such piles of iron, and have frequently been called upon to locate the cause of trouble in irons due to supposed hoodoo iron. I am not at all

a believer in hoodoo iron, but believe that all foundry irons are good iron, if one knows how to mix and melt them properly, and I have never found a hoodoo iron that I was not able to mix and melt to produce a good iron for the work to be cast, from fracture indications alone. This should be a very easy matter to do for a man familiar with the chemistry of foundry iron.

The characteristics of the various grades of cast iron are given to them by the controlling or predominating metalloid in the iron. Thus graphite carbon control gives a soft iron, combined carbon a hard iron, silicon is the controller of carbon in cast iron, and by decreasing the silicon in a soft iron it is made a harder iron, and by increasing the silicon in a hard iron, it is made a softer iron. This may be decreased to an extent that makes a very soft iron a white iron, or increased to an extent that makes a white iron a very soft iron, and thus remove the hoodoo of either a too soft or hard iron.

Sulphur, when in control, hardens iron; silicon, when in control, softens iron, and it is only necessary to increase the silicon to remove the hoodoo of sulphur-hardened iron. Manganese is a hardener of iron when in control, but silicon is a controller of the hardening effect of manganese, and an increase of silicon removes this hoodoo. Ninety per cent. of the hoodoo pig piled in foundry yards can be made a good iron by these simple remedies, and it is only necessary to carry a few tons of high or low metalloid pig to be placed in mixtures to eliminate these hoo-doo's from any iron.

The hoodoo pig is described under testing pig iron, upon a more thorough analysis was found to contain titanium. Titanium is classed as a strengthener and hardener of iron, as is also manganese. The two other brands of pig with which this iron was melted were probably high in manganese and this, combined with the titanium to form a hardening metalloid, that overcame the silicon and reduced the graphite carbon to a point that the castings were hard. The preventative for this hardening would have been to melt this pig with a low manganese pig or scrap, which would decrease the hardening tendency of the titanium, and, in case the iron was too hard, increase the silicon of the mixture.

The hoodoo iron described under sandwich hard spots proved not to be a hoodoo iron at all, but only an iron that ran a little too hard for stove plate. This is a mistake that foundrymen are liable to make, and blame their iron troubles on the wrong iron, when the real cause of their trouble is in their supposed best iron. To avoid making this mistake, the per cent. of

the best iron in the mixture should be varied as well as the poorest in making test mixtures. The real hoodoo iron in this case proved to be the one presumed to be the best iron in the mixture, and one that had been used as the leading iron for years, but a change had been made in the mixture of ores from which it was smelted, which made it the poorest.

This iron was withdrawn from the market by a change in the mixture of ores, and I never learned just what caused this peculiarity of the irons. But it was either due to a metalloid that did not unite properly with the iron, smelted very hot, or to the iron being burned in smelting by the furnace working very hot. For it was not so marked in the No. 2 as in the No. 1, and entirely disappeared in the No. 3, which was smelted at a lower temperature.

About the time these tests were made at Albany, I found a large pile of hoodoo iron at The Union Stove Works, Peekskill, N. Y., which had lain in the yard for ten years; this iron I did not attempt to melt with a No. 1 pig, after hearing their account of failures to use it, and my experience with No. 1 pig at Albany. But selecting by fracture indications an inferior pig from their stock of pig on hand made them a very fine iron for stove plate, with a high per cent. of the hoodoo iron in the mixture.

Hardness and Small Blow Holes.

Hardness and small blow holes are frequently found on the top of thin castings poured from the bottom, in which case the iron is required to rise to the top of the mould between walls of damp sand, or between the walls of the mould and green sand cores, as in the casting of cylinders from which piston packing rings are to be cut. This hardness may be due to the sand being worked too wet, and chilling the iron as it rises in the mould. In which case the first iron rising would dry the sand and be the only iron to be chilled, and hardness would only be found at the top of the casting. This hardness may occur when the castings are gated either at the top or bottom, but it is more extended when poured from the bottom. This hardness may be prevented by working the sand as dry as possible, or flowing the first iron out of the mould through a riser or into an ingot alongside of the mould, through a gate from the casting to the ingot. Hardness and small blow holes are frequently due to too much care being taken in making a parting, such as ramming or packing the sand too hard around the pattern, to prevent ramming down, slicking with the trowel which closes up the pores of the sand and pre-

vents the escape of gas from the sand and mould as rapidly as it should escape, or to swabbing to an extent that makes the sand so wet the molten iron will not lie quietly against it, which results in hardness and blow holes. To prevent this hardness and blow holes, carefully avoid all the above objectionable features in making the mould. Pour with a very hot iron, and if this does not prove a preventative, draw the first, or chilled, iron out of the mould through a riser or into an ingot or button. This precaution as a preventative applies to any castings, as well as those described where the hardness and blow holes appear along the parting line of the casting.

Hardening Due to Chilling of the Iron by Sand.

Many castings are condemned due to the iron being chilled by the damp sand of the mould to an extent that makes it a white iron or prevents it running up sharp in corners.

This kind of hardness only appears in light castings at the furthest point from the gate, and may be prevented by permitting the chilled iron to flow out of the mould and replacing it with hot iron. To illustrate the method of doing this, I will take an automobile cylinder packing ring. It has been found that these rings when cast separately and only turned on the outer side, give better results than when cut from a packing ring cylinder. These rings are so light that when cast four on a gate they frequently run very hard at the furthest point from the gate, with the softest of iron. This hardness may be prevented by casting a small button of iron in the center of the ring and connecting it with the ring at the furthest point from the gate by a small gate or runner; this permits the first iron, chilled and hardened by the cold sand, to flow into the button and its place to be taken by hot fluid iron, which prevents any hardness in the ring. A button weighing only one ounce is sufficient to prevent this hardness in the ring.

This is the button system of preventing hardness in light castings, and it may be applied to any light castings, and one or more buttons attached to the same casting. A round or any shaped button may be cast; the important point to be considered is the placing of the button at the point where the hardness occurs, and to have the button of a size that will remove all the chilled iron from the mould.

To prevent hardness in corners and have the corner run up sharp and square, a wedge shape button may be cast upon the

corner, with the sharp point of the wedge attached to the casting. This will permit chilled or dull iron to run out of the mould and the corner to be filled up with sharp fluid iron, and the wedge when broken off leaves a perfect corner on the casting.

This system may also be applied to castings gated at the bottom, in which the iron is required to flow upwards around a green or dry sand core, to prevent hardness of the casting, and also small blow holes, by removing dull iron from the moulds. This removes the objectionable feature of a riser on the casting, admitting air to the mould. Dull iron may be removed from sharp points or corners in a cope, when a button cannot be placed, by punching a hole in the sand into which the dull iron can flow.

Iron Poured Hot or Dull.

The following questions were recently asked me by one of our students: "What is the difference in the castings in the first iron poured from a ladle when the iron is hot, and that poured from the same ladle when the iron has become dull during the pouring, so as to empty the ladle?" This matter was tested by a committee appointed by the American Foundrymen's Association casting test bars to establish a standard for the strength of casting. Two bars were cast from a ladle of very hot fluid; the remainder of the iron was then permitted to stand in the ladle until it became quite dull, and two more bars were cast. The average strength of the first two bars cast was practically the same as the average of the last two cast, and there were no perceptible differences in the fracture indication or the machining qualities of the iron. The only change that is likely to occur in this case is in the dull iron poured castings being dirty and containing small blow holes, due to lack of heat and fluidity in the iron.

Chill on Castings.

To make a small chilled roll or a few chilled castings, in which there is not sufficient weight to make a special charge of iron, melt a little scrap or close pig at the end of a heat and add to it in the ladle all the steel turnings the iron will melt and absorb. With a close iron to begin with, and a very hot iron, about 5 per cent. clean steel ribbon turnings can be melted in this way and the iron strengthened and hardened to an extent that a deep chill may be attained upon a small roll or a comparatively light casting. If the iron is very soft and open the chill will not be deep, and it is only with a close iron that a satis-

factory chill may be obtained in this way. The depth of the chill may be regulated by the per cent. of steel added to the iron.

Theory of Melting Scrap.

It is generally considered that a mixture of different ores makes a better iron than one ore alone, and this theory is followed by foundrymen, who generally aim to use pig iron from more than one furnace, in a mixture of iron, that they may have blending of irons, and stronger, cleaner and better castings. This is one of the principal reasons for using scrap, for in so doing they generally get a large variety of iron in their mixtures, and for this reason foundrymen making castings for which a superior quality of iron is required, frequently are willing to pay more for good machinery scrap than for pig.

This theory is so strongly adhered to by many founders that they will not cast an important casting, in which strength and wearing qualities are required, without scrap in their mixture. For such castings only selected scrap is used; the scrap selected depends upon the quality of iron desired in the casting. For a soft, strong casting, clean, soft, strong machinery scrap is chosen. For a close or hard casting, a close or hard scrap, such as chilled car wheels, is used. This scrap theory is more commonly applied to heavy castings, but many jobbing foundries also apply it to their mixtures. This is a very old theory that has been practised by foundrymen for years, but the present generation of foundrymen do not adhere to it so strictly as the former, for it has been found that as good castings can be made from all pig from different furnaces as by the use of scrap, and in mixtures by analysis, a desired quality of iron may be obtained in castings with more certainty from all pig than with scrap, the exact analysis of which cannot be determined.

Another reason given by foundrymen for using scrap is to cheapen their mixture. This will be considered under the heading of "Iron Lost and Gained in Melting."

Loss and Gain of Iron in Melting

CHAPTER VI.

Loss of Iron in Melting.

It is a very difficult matter to determine the per cent. actually lost in melting iron, owing to the carelessness of cupola men in weighing the iron that goes into the cupola, and in the practice of distributing molten iron, collecting castings, over-iron, recovering iron from the dump, etc. In more than a hundred heats, melted by the writer, in different foundries for various classes of work, to determine the loss in melting for these classes of work, the results were found to vary from a gain of 3 per cent. to a loss of 20 per cent. on the regular foundry mixture. This would no doubt be the experience of a majority of foundrymen today, if they were to attempt to ascertain their loss in melting and trusting to the weights of cupola men and others. Full 50 per cent. of these heats were manifestly incorrect, and it was only by correcting the system of weighing and collecting iron in castings and remelt, and trying again, that any conclusion could be reached. From these heats it was concluded that the loss in melting for different classes of work was about as follows:

Pig and remelt for heavy machinery castings, 3 per cent.

Pig and remelt scrap for light machinery and jobbing work, 4 per cent.

Pig and remelt for stove plate and bench work, 5 to 6 per cent.

The increase in loss is due to the increase in light remelt scrap, which varied, in stove and bench foundries in which the

tests were made, to from 30 to 50 per cent. of the heat. These tests were made from the regular foundry mixture for the class of work indicated. And the loss, which is almost double in stove and bench work foundries, is due to the heavy remelt of small gates and scrap. The following estimate of loss upon pig and old scrap, were made for the various lines of castings with the average mixture and remelt for such work.

Pig and heavy machinery scrap for heavy work, 3 per cent.

Pig and small machinery scrap for light machinery, 5 per cent.

Pig and promiscuous scrap for jobbing work, 7 per cent.

Pig and old stove plate, plain work, 9 per cent.

These losses indicate those on an entire heat of these irons, and, as all these mixtures are frequently melted in one heat in jobbing foundries, show the average loss to be 6 per cent. This loss will vary to some extent to the amount of each grade of scrap in the mixture melted. It also varies with the size of heat melted, and in all cases is greater in light heats than in heavy ones, due to a larger per cent. of shot iron and cupola waste. These losses were determined before the new methods of recovering all the shot and small pieces of iron were introduced. But as these small particles that were formerly thrown away are probably all burned up in melting, a test in which they are melted with the regular mixture will probably show about the same loss.

Loss in Melting Machinery Scrap.

The loss in melting machinery scrap varies with its quality. With a heavy clean scrap, it is not any greater than that of pig iron. And with light scrap, rusted and dirty, it varies according to the size of the scrap, and runs as high as 7 per cent.

Loss in Melting Old Stove Plate Scrap.

In a number of heats of all old stove plate, melted in different foundries to determine the loss in melting, it was found to be from 10 to 15 per cent., it varying with the extent to which the plate was rusted and the care with which it was picked over. This was the actual loss in melting and does not cover the total loss on this iron. This scrap, when piled in the yard and exposed to the weather, oxidizes very rapidly, iron being thus lost. Many small pieces are lost in the yard in breaking up the stoves, and

the latter frequently contain ashes and dirt, which have been weighed as iron. Badly burned pieces, such as grates, fire-plates, covers, cross-pieces, etc., are generally thrown out, all of which increases the loss on weight of iron purchased. Taking all these losses into consideration, practical foundrymen figure the loss on this scrap at from 12 to 20 per cent. New plate from the foundry is considered at 6 per cent. loss.

Loss in Melting Plow Point Scrap.

In a number of heats melted at Albany, N. Y., of scrap selected from a promiscuous pile to determine the loss on different scraps, it was found that plow points showed the smallest loss in melting of any of the small scraps. This loss, as indicated by a number of heats, was 4 per cent.

Loss in Melting Shot Iron.

The writer has made many curious tests to determine the loss in melting this iron. Among them was one made at the foundry of the Perry Stove Works, Albany, N. Y. They had a lot of shot iron that had become mixed with small anthracite coal and it was determined to burn the coal under the boilers, and in this way melt the iron and permit it to drop into the ash-pit, from which all ashes had been removed and a hole arranged in the center into which the iron would run and form a solid mass. A good hot fire was prepared under the boilers, and a thick layer of shot and coal spread over it. The ash pit doors were then tightly closed and a blast turned into the ash pit. Mica had previously been put into the furnace doors so that the effect of the heat upon the iron might be seen. When the iron upon the surface came near the melting point, the small shot threw off beautiful bright stars of all colors and shapes, presenting the appearance of fireworks. In these stars all the small particles of iron were converted into the black oxide of iron. The iron under the surface must have gone the same way, for none of it was found in the ash-pit or upon the grate bars, although fully 300 pounds were placed in the furnace. This seems to indicate that in melting this iron it should be excluded from the air as much as possible and melted quickly to reduce loss.

In a heat of one ton of shot put up in wooden boxes and melted at the same foundry the loss was 20 per cent. This shot was to some extent composed of vents, rods, fins, etc., which had been recovered from the sand heaps and was considerably rusted. The iron obtained was very hard, although the shot had been made from very soft stove-plate iron.

In a heat melted at a stove works in Louisville, Ky., in which 1000 pounds of shot were charged loose on the bed and the regular heat for stove plate melted with it, the loss on the entire heat of five tons was 8 per cent. The cupola melted slower than usual, which was probably due to the slag and dirt from the shot covering the bed and clogging the cupola.

In a heat melted at the Baldwin Locomotive Works, Philadelphia, Pa., in 1874, the loss was 15 per cent., with the shot put up in wooden boxes, and the iron obtained was very hard.

In a heat melted at the Fort Pitt Foundry, Pittsburgh, Pa., the loss was 18 per cent. The shot was smaller than that at the Baldwin works, and was put up in wooden boxes and melted in the same way; iron very hard and unfit for anything but weights.

Rust increases the loss on this iron, and also the hardness. It should never be permitted to accumulate about a foundry.

Loss in Melting Burned Iron.

When managing a malleable iron foundry in 1873, we accumulated quite a lot of old annealing boxes for which there was no market, and it was decided to try melting them in a cupola and running the iron into boxes or pig for use in our regular mixture. Some of these boxes were cast from white iron, and others from grey iron. The grey iron boxes, which were heavier than the white iron ones, were tried first. We obtained from them about 40 per cent. of very hard iron, with a large amount of slag, which was so mixed with the iron that it could not be separated from it until cooled. The white iron boxes produced about 50 per cent. of iron, which was also combined with the slag; and they required more fuel to melt than the grey iron boxes.

In a heat I melted at the American Stove and Hollow Ware Co., Philadelphia, Pa., in 1874, of annealing pots that had been used in annealing hollow ware, the loss was 30 per cent., with so large a per cent. of slag that the iron could not be run into the castings for which it was melted.

These pots were 2 inches thick and had not been subjected to so great a heat as the malleable annealing boxes.

In a heat, melted at Norfolk, Va., of the ends of grate bars that had not been in the fire and showed but little signs of having been heated, the fracture indicating a soft iron, the loss in melting was 18 per cent. The iron was white, hard and brittle, but slag was not excessive and separated readily from the molten iron. These bars were cast at a locomotive works from soft iron.

In a heat melted at the foundry of Noyes & Co., Buffalo, N. Y., of hot-blast pipe that had been used in heating blast for drying purposes, the loss was 25 per cent. This pipe had not been heated to a very high temperature and showed but little indications of having been burned.

The iron obtained from burned iron is only fit for weights, and probably the best way to melt the latter for this purpose is to mix it in small quantities with other scrap. The slag then acts as a flux for the cupola.

Loss and Gain in Melting Pig and Scrap Iron.

The following tables show the loss and gain in melting pig iron, and the loss in melting scrap iron.

Gain in Melting Pig Iron.

Gain in melting 100 tons of pig iron bought in gross tons of 2,240 lbs., and castings sold in net tons or pounds. 100 gross tons are equal to 112 net tons, and, therefore, there is a gain in iron on all losses under 12 per cent.

Iron.	Per cent. lost in melting.	Iron lost.	Iron gained.	Castings.
100 Tons.	3	3 Tons.	9 Tons.	109 Tons.
100 "	4	4 "	8 "	108 "
100 "	5	5 "	7 "	107 "
100 "	6	6 "	6 "	106 "
100 "	7	7 "	5 "	105 "
100 "	8	8 "	4 "	104 "
100 "	9	9 "	3 "	103 "
100 "	10	10 "	2 "	102 "
100 "	11	11 "	1 "	101 "
100 "	12	12 "	0 "	100 "

Loss In Melting Scrap.

Loss in melting 100 tons of scrap iron bought in net tons and sold as net tons or pounds:

Iron.	Per cent. lost in melting.	Iron lost.	Castings.
100 Tons.	3	3 Tons.	97 Tons.
100 "	4	4 "	96 "
100 "	5	5 "	95 "
100 "	6	6 "	94 "
100 "	7	7 "	93 "
100 "	8	8 "	92 "
100 "	9	9 "	91 "
100 "	10	10 "	90 "
100 "	11	11 "	89 "
100 "	12	12 "	88 "

A comparison of these two tables shows that there is a gain of 12 tons of castings in favor of the pig iron against the scrap, when the percentage of loss in melting each is the same, while only in the melting of heavy machinery scrap the loss is the same as that of pig iron, it being heavier in all other grades of scrap until old stove plate is reached with which it may be 15 per cent. In this case only 85 tons of castings could be produced from 100 tons of scrap. Pig iron should, and can be, melted in a well-managed cupola with a loss not to exceed 3 per cent. for heavy castings, where the remelt is light and the remelt scrap comparatively heavy. By allowing 5 per cent. loss in melting pig and 7 per cent. loss on light scrap there is a difference of 14 tons of castings in favor of pig, and a still greater difference as the scrap becomes smaller and poorer. These figures and tables should convince any founder that the price at which scrap is now being sold is entirely too high in comparison with the price of pig. In some foundry districts scrap is sold in gross tons of 2240 lbs., but even in these districts the price is too high to be profitable to the founder, for at least 2 to 3 per cent. more iron is lost in melting, and more labor is required to handle scrap, because one man can load and deliver two to three barrows or trucks full of pig, while another one is loading and delivering one of small scrap, a greater expense for labor being thus incurred.

These matters should all be taken into consideration and investigated in figuring cost of castings. When this has been done the price of scrap will no doubt come down on a par with that paid in the days of rule of thumb foundry practice, when founders evidently knew more about the value of scrap in foundry than the scientific founders of to-day.

No more than \$12 per ton is at the present time paid for rolled-plate steel scrap by the manufacturers of steel, and the ratio of difference in price should exist between that of pig and scrap as between that of steel and scrap steel.

Stove Foundry Melting.

The following tables show statements of melting per cent. of castings, remelt, fuel and gain in iron, which were furnished by four of the leading stove foundries of Albany and Troy, N. Y., and published in my work, the "Founding of Metals" in 1877; they represent the melting and output of these foundries for the year 1876. At that time Albany and Troy were the leading stove centers of this country. Stove founders have always been noted for better cupola practice than machinery and jobbing founders.

These reports show more accurately and completely what may be done in cupola practice than any reports I have ever seen published:

FIRST FOUNDRY.

	Tons.	Lbs.
Gross amount of iron melted.....	2,049	1,087
Amount of pig melted.....	1,300	1,860
Amount of clean castings net.....	1,344	919
Percentage of cleaned casting produced to total iron melted		57.70
Percentage of coal used in melting.....		15.55

SECOND FOUNDRY.

	Tons.	Lbs.
Gross amount of iron melted.....	2,817	1,420
Amount of pig iron melted.....	1,842	1,871
Percentage of cleaned castings produced to total iron melted		62.12
Percentage of fuel used in melting.....		14.51

THIRD FOUNDRY.

	Tons.	Lbs.
Gross amount of iron melted	3,328	84
Amount of pig iron melted.....	2,118	421
Amount of cleaned castings net.....	2,216	987
Percentage of cleaned castings produced to total iron melted		56.35
Percentage of coal used in melting.....		16.12

The following statement was received from the largest stove foundry in the United States at the time it was made:

	Tons.	Lbs.
Gross amount of iron melted.....	6,695	1,197
Amount of pig iron melted.....	4,276	1,042
Amount of cleaned castings net.....	4,433	975
Net gain of castings over gross tons of pig iron.....	157	
Percentage of cleaned castings produced to total iron melted		58.41
Percentage of coal used in melting		15.08

This last table shows the melting done and results obtained at the Perry Stove Works, Albany, N. Y., for the year 1876, and was prepared by Mr. John S. Perry, the great pioneer of modern stove and range designs and construction, and the most accurate figurer of foundry cost this country or any other has ever produced. But Mr. Perry died a poor man, while his com-

petitors grew rich, which very clearly indicates that success in foundry practice does not all depend upon an accurate cost of production system.

This report, leaving off the odd pounds or fraction of a ton, shows that 4,276 gross tons of iron were melted. Reducing this amount to net tons, the same as cleaned castings, there is a gain of 513 tons in pig, making a total of 4,789 tons of pig melted; deduct from this the weight of cleaned castings, 4,433 tons, and there is a loss of 356 tons of iron in melting or 7.43 per cent. on the pig. Take from the 4,433 tons of castings, the 4,276 gross tons of pig, or the 356 tons lost in melting from the 513 net tons gained in reducing 4,276 gross tons to net, and there is to the founder a gain in iron of 157 tons in castings in the melting and casting of 4,276 gross tons of pig. The total amount melted was 6,695 tons, or 906 tons more than the net tons of pig. No old scrap was melted and this amount represents the remelt, which was 41.59 per cent. of the total amount melted in each heat. The loss on total amount melted, 6,695 tons, was 356 tons, the same as on the pig, but shows a per cent. loss of 5.31 as against 7.43 on the pig, or 2.12 less than the pig.

This heavier loss on the pig was due to the remelt of 41.59 per cent., or 906 tons, which had to be melted twice before it was put into castings. These figures of per cent. of loss in melting show the fallacy of figuring the loss in melting on a test heat to determine that in melting, for the pig or scrap purchased and paid for is the only iron on which the loss is sustained.

These heats were all melted with anthracite coal as fuel, but little used for the purpose at the present time, and show the per cent. of this fuel required to melt iron sufficiently hot for light stove plate. The figures given are the per cent. of fuel consumed in melting 100 pounds of iron, and not pounds of iron melted to the pound of fuel.

Determining Actual Loss of Iron.

It is interesting and of value to know the actual loss of iron in melting in a well-managed cupola. Such a knowledge serves to keep down the loss from excessive blast, scanty fuel, carelessness in recovering iron from dumps, gangways, etc. But loss in melting by no means indicates the loss of iron that the founder is liable to. In soft foundry yards a great deal of iron may be lost by sinking into the ground in wet weather. I visited a foundry at Hartford, Conn., some years ago, to which an addition was being built over the iron yard. In digging the trench for the

foundation for this addition, twenty bars of pig iron were recovered, and had the entire yard been dug over, many tons of iron would no doubt have been found. Many small pieces of iron are lost in breaking scrap in these yards, and two or three feet in depth of almost solid iron may be found in yards where scrap has been broken for years. Iron is buried in the foundry in sand and refuse. Bad castings have been buried and thrown in ponds or rivers by moulders to conceal poor moulding and loss of castings, and there are many other ways in which iron may be lost. The best method, therefore, of determining loss of iron is not to depend upon the cupola report for it, but to reduce gross tons of iron to net tons or pounds and compare this with pounds of castings sold or on hand, and visible stock of iron on hand, because all stock not visible is lost, whether it has gone up the cupola stack or lost in some of the many other ways in which it may disappear from view.

Castings by Direct Process.

In the early days of founding, castings were cast with molten iron taken direct from the furnace in which the ore was smelted and the iron made. In those days the remelting of iron for castings was not practiced, and all castings, light and heavy, were cast direct from the furnace. The iron from many of the ores smelted was not suitable for castings, and this prevented many of the furnacemen from engaging in the business, while those having ores that produced a suitable grade of iron for castings met with such difficulty and uncertainty in obtaining the grade of iron desired, owing to the lack of knowledge in controlling the furnace, that the business was not very profitable. This led to the invention of the cupola and to the remelting of iron found suitable by fracture-indication for the work to be cast, and to the separation of the casting industry from that of the blast furnace, and the establishment of foundry practice as a separate and distinct branch. For many years no castings were made at blast furnaces except plain ones for their own use or for rolling mills with which they were connected. But since the improvements in the mixing of ores and blast-furnace practice, some furnacemen have again engaged in the casting business. This is now known as the direct casting process. Even with the improvements in blast-furnace practice and the aid of chemistry in mixing ores, the furnacemen are not always able to control the quality of iron or produce a grade suitable for castings the molds for which have been made. Before the quality of the metal can be determined the work is cast, and the castings have to be broken up in case the iron proves unsatisfactory, and the latter has to be run into

pigs, sometimes for several days, before the furnace gets back into its normal working condition and produces a soft, even iron. But for certain lines of heavy castings, such as steel ingot molds, the direct process has proven a success, and these molds are regularly cast at furnaces. Aside from the liability of the iron to run too hard for the castings, is the trouble caused by kish* found in iron high in graphite, such as soft high-grade iron. This substance in appearance resembles flakes of black lead or plumbago, and is the same flaky carbon material so often found separating the crystals of pig iron and falling out when the pig is broken. It frequently separates from a cast of soft foundry or Bessemer iron, and floats off in the air in such large quantities as to cover the floor of the casting house. It appears to separate to a far greater extent when the iron is caught in ladles than when it runs through a runner direct to the pig beds in the floor of the casting house. All the excess of it is thrown out of the iron before cooling and does not appear when the iron is remelted, except in rare instances. But in casting by the direct process kish is a great annoyance. It forms cold shots, spongy, porous spots in the castings, and floats upon the surface of the molten iron as it fills the mold, and gives to the top of the casting a rough, ragged appearance that often condemns the latter. Kish cannot be skimmed from the surface of the iron before pouring, and a number of gates devised to prevent it entering the casting and to collect it in the runner or gate have proved a failure, for the kish is in combination with the iron when it enters the mold and separates as the latter fills and the iron cools. For this reason it may be said that iron possessing much kish is unfit for pouring small or fine castings to be machined and finished. Kish seldom appears in iron with silicon at or below 1.5 per cent. and sulphur above 0.30 per cent., and good sound castings can be made with such iron by the direct process. But iron with such a low content of silicon is too hard for light soft castings and can only be used for castings an inch or more in thickness. This has been the experience at many of the furnaces at which the direct process has been tried, but some of them appear to have had less trouble with kish than others, and turned out satisfactory small castings. That castings can be made cheaper by the direct process than the founder can remelt the iron and produce them is undisputed, and quite a number of ingot-mould foundries have been compelled to look for other work, due to direct process competition. In some sections foundries have refused to buy pig from furnaces

* Kish, thrown off from iron in direct casting has been analyzed and found not to be black-lead or plumbago, although in appearance it resembles it very closely.

making castings by the direct process, claiming they only want to sell the iron they can not use in the production of castings and in cutting of prices. But such a course would seem to be unnecessary as owing to the uncertainty of the quality of grade of iron a furnace may from day to day produce and the presence of kish in iron suitable for soft castings, the furnacemen are not likely to engage in the general casting business.

Oxidized Iron.

This term is applied to iron that has been changed from its normal condition by the action of the elements or by heat, and in plain terms, as applied to foundry irons, means rusted and burned iron. Thin sheets of iron, such as tinned plate, from which the tinning has been removed, stove pipe, etc., may in a very short time be completely destroyed by rust if placed out of doors or in a damp place. Cast iron is destroyed in the same way, though not so rapidly as wrought iron or steel, but when exposed to the elements it becomes heavily coated with rust, and it too is in time completely destroyed, and the greater the surface exposed the more rapid the destruction. Rust does not affect cast iron beyond the depth or scale of it, and when this is removed the iron is found to be perfectly solid and not at all deteriorated. When cast iron heavily coated with rust is heated, the action of the latter upon it is similar to that of rusted iron scale used for annealing in malleable works, and extracts carbon from the iron, rendering it harder when melted. This hardening effect of the oxide can be prevented by removing the rust, which can readily be effected with small scrap, by placing the latter in tumbling barrels and tumbling it for a short time. This cannot be so readily done with larger scrap, and besides the iron is not hardened to so great an extent as is the case with small scrap, which exposes a greater surface, in proportion to the body of iron, to oxidation than heavy scrap. That the value of cast iron is decreased by rusting is well known, and pig iron that has for years lain in storage yards to be sold upon the warrant system is sold at a lower price than new iron of the same grade. The value of scrap is to a still greater extent deteriorated by rusting than pig iron, for a far greater area of surface, in proportion to the body or weight of iron, is exposed to the action of the elements. For this reason scrap should be kept upon a dry floor under cover and not be permitted to lie upon the ground in the foundry yard, and it should be melted as soon as possible after being received at the foundry. Small iron more especially should not be permitted to rust, for the latter not only diminishes the quantity of this iron, but also the quality, for when melted with a heavy coating of rust

upon it, its characteristics are changed to so great an extent that it does not mix with the same grade of iron from which it was cast to make a homogeneous metal. The quality of this iron is not at all improved by running into pigs and remelting.

Oxidation of Iron by Heat.

Oxidation of iron by heat differs from that by rust in the entire body of iron being deteriorated or destroyed without a decrease in size or an indication in the fresh fracture of the change that has been effected. This oxidation is caused by a prolonged heat, or repeated heating and cooling, as well as by the action of the atmosphere and products of combustion upon the iron, and may take place when the iron is enclosed in a furnace, as, for instance, at retorts, or heated in the open air as grate bars. In either case the oxidation of the iron is complete if the heating is sufficiently prolonged. This form of oxidation cannot be removed the same as rust so that a good quality of iron is still left, but the iron has to be melted in combination with its oxide. The effect of the oxide is to destroy the strength and softness of the iron, the latter when separated from it by melting being always hard and brittle. The extent to which the strength and softness of the iron are affected varies with the extent to which it has been oxidized, as does also its action when melted. A very badly burned iron when melted in a cupola produces a very fluid slag which flows from the tap hole like iron and in combination with the iron the oxide contained. As the slag cools the excess of iron it is not able to hold, the latter separates and sinks to the bottom, and the more slowly the slag is cooled the greater the per cent. of iron recovered from it will be. The greater the per cent. of iron the burned iron contains the more readily it will separate from the slag, and when not too badly burned may separate from it in the cupola or be skimmed from the ladle, the slag retaining but a very small per cent. of iron, and the iron cannot be poured into castings if the oxide is in excess. That an iron has been oxidized by heat is not always indicated in the fresh fracture. In fact, the latter almost invariably indicates a fine grade of soft iron; nor is the outward appearance always an evidence of oxidation by heat, and it is frequently only by the shape of the casting, or a knowledge of the use to which it has been put, that an iron oxidized by heat can be detected. Oxidized iron when remelted always produces a harder and weaker iron than that from which it was cast, and in extreme cases of oxidation a very hard, brittle iron that does not mix readily with others so as to make a homogeneous metal. Such iron should not be mixed with others for

soft castings, and it is only fit for an inferior grade of castings even when but slightly oxidized, and for weights when badly oxidized.

Sash Weight Metals.

The only properties required in sash weights are weight and sufficient strength to stand shipment and handling. They may be cast as over iron at the last of a heat or from any old scrap thrown into the cupola at the latter end of a heat, as is frequently done. But in regular sash weight foundries they are cast from any old metal that can be purchased at a low price, such as blast furnace scrap, pig that has been condemned for any other casting, old cast-scrap, burned iron, shot iron, malleable scrap, wrought scrap, steel scrap, tin scrap, steel wire, sheet iron, tin cans, gas pipe, galvanized iron, tin roofing, horse shoes, and, in fact, any old metal that is of little or no use for anything else. These metals are mixed so as not to get a sufficient quantity of any one kind that is more difficult to melt than another in one place or charge and clog the cupola, and a little cast iron, if at hand, is distributed through the heat. This melts more rapidly than the other metals, tends to keep the cupola working more open and free, and also to give life to the other metals when melted. This metal sets very rapidly after being drawn from the cupola and therefore requires to be melted very hot, and handled very quickly to run the weights. It is the practice to use large gates and runners, or construct a basin and dump the metal right in so that the mold may be filled as quickly as possible.

This metal may be melted in any ordinary cupola and is sometimes melted after the regular heat of cast iron has been melted without any bad effect upon the iron in this or the following heat. But as the metal is very hard, separate ladles should be used for it or the ladles newly daubed throughout for every heat to prevent small particles of iron from adhering to the ladle and hardening the soft iron. An extra amount of fuel is required to melt this metal hot, and the average melting is about three pounds of metal to one of fuel. To increase the fuel the weight of the charges of it should be permitted to remain the same as for cast iron, and the weight of the metal in each charge be decreased until a hot metal is secured.

Sash weight metal of this kind is neither a cast iron, wrought iron or steel, but a mixture of all of them, and a product that is

very hard and brittle and inferior to any one of the metals in the mixture from which it is cast.

Temper in Cast Iron.

The melting and casting of iron impart to the casting or iron when cold a certain degree of elasticity which may be called temper, but the drawing of this temper by heating after the casting has become cold reduces the elasticity of the iron and renders it more rigid and readily broken. This may be illustrated by the light oven plates of cooking stoves, ranges, etc. When new these plates, if warped or twisted, are readily sprung into place by the mounter, but after they have been heated to the degree required for baking in the oven, which is not even a dull red heat, become rigid and devoid of elasticity. This is the case with all soft cast iron, and the higher the temperature of the iron when cast and the more rapidly it sets in the mold up to a certain point, the higher the temper and greater the elasticity, as may be seen in the deflection of test bars. But the reverse is the case with a hard or chilled iron in which elasticity is increased by annealing. This temper exists in all soft cast iron, but is more apparent in a charcoal iron than in a coke iron, and in a close or fine-grained iron than in an open one. For many lines of castings, temper in iron is of no consequence whatever, but for others it is of great importance, and the drawing of it by heating or annealing renders the casting useless for the purpos for which it is designed. This is the case in all castings requiring a certain amount of elasticity or spring, such as that required in steam cylinder packing rings. To draw the temper from cast iron does not require a high or prolonged heat, as in annealing, to soften or remove shrinkage strain, but it may be drawn by heating in turning up a light casting in a lathe with a high speed tool steel or a dull low speed tool. This has been repeatedly shown to be the case in turning up cylinders from which small light automobile packing rings were to be cut. In this case the rings cut from the end of the cylinder, at which the sharp tool was started, had the desired elasticity and spring, while those from the other end, which had become heated by a high speed or dull tool, possessed no spring whatever, and were perfectly useless as packing rings. When the temper in cast iron has once been drawn, it cannot be returned to it by any known process, except that of remelting and casting, for it is imparted to the iron by the formation of the crystalline structure when it sets and cools. The heating of it changes the formation of

the crystals to the extent of removing the strain upon them, that gives to the iron the desired temper or spring.

Automobile Cylinder Packing Rings.

One of the most difficult irons to produce is a satisfactory one for automobile cylinder packing rings, and probably more experimenting has been done in the production of this iron than in that for any other casting made in recent years. These rings are very light and require a certain amount of spring that is difficult to procure in turned and finished cast iron. Probably every brand of iron in this country known to possess peculiar characteristics has been tried, and irons have been imported from other countries for these castings with no better results than with the home product. Besides the various irons possessing distinct characteristics and mixtures of them, all the known elements in metal that give to iron elasticity and spring have been added to molten iron in the ladle in endeavors to obtain a satisfactory ring. One of the most expensive of these elements or metals to be tried was vanadium. This metal has been added to iron to the extent of the cost of forty dollars per ton of iron with very satisfactory results in the ring obtained from this alloy, but with no more certainty of results than from mixtures of iron without the vanadium, for it has been found that only under certain undetermined conditions does vanadium enter into combination with cast iron to give to it this desired characteristic. The work done in this direction has therefore been largely experimental, and I am not aware that this metal or alloy has been adopted by any of the automobile foundries for these rings. The metal generally used for them is a mixture of strong Lake Superior iron, ten to twenty per cent. steel, and, in some cases, ten to twenty per cent. charcoal iron. This mixture, which is the same as that made for the cylinders, gives, when containing the proper amount of silicon and carbon to insure its being soft, the required amount of elasticity and strength for the rings, provided the temper is not drawn from the casting by heating in turning and finishing.

Ferro-Alloys

CHAPTER VII

Owing to the fact that many of the ferro-alloys have only been in use for a comparatively short time, the fixed standards have not in many cases been adopted. One company designates its material by showing the number of units of carbon by "X" and the kind of alloy by its letter symbol, thus a ferro-chrome containing 9.70 carbon, it would designate 9 x C.

All foreign ferro-alloys are sold to the American consumers f. o. b. cars American seaboard, based on present duties, United States custom-house weights at seaboard to govern settlement, and upon certificate of foreign chemist of repute to be conclusive as to quality.

Ferro-Aluminum.

Ferro-aluminum is sold containing 10 per cent. aluminum. Higher percentages are also used in iron and steel, No. 1 being guaranteed over 99 per cent. pure aluminum. No. 2 is guaranteed over 90 per cent aluminum, with no injurious impurities for alloying with iron and steel. It is sold by the pound.

This is an alloy of silicon, aluminum, manganese and iron. One partial analysis showed:

Silicon	8.01	per cent.
Aluminum	6.80	"
Manganese	8.39	"
Phosphorus	0.075	"

Ferro-Chrome.

Ferro-chrome usually runs 60 per cent. to 68 per cent. chromium. It is graded per unit of chromium and per unit of carbon,

the price increasing with the chromium and decreasing with the increase in carbon, these elements being guaranteed. If low in carbon, it is sometimes called "mild."

A typical analysis only guaranteed as above is as follows:

	Mild, per cent.	Ordinary, per cent.
Chromium.....	64.80	66.00
Iron	33.43	21.91
Carbon	1.21	9.90
Silicon	0.29	1.40
Phosphorus	0.027	0.07
Sulphur	2.02	0.22
Manganese	0.09	0.20
Copper	0.12	...
Aluminum .....	....	....

It is sold per ton, 2,240 pounds.

Ferro-Manganese.

Ferro-manganese contains over 40 per cent. manganese.

Standard ferro-manganese is only guaranteed to average 80 per cent. or over manganese. The English runs lower in phosphorus than that from the continent. A typical analysis, manganese only guaranteed, is as follows:

	English,
Manganese	80.50 per cent.
Iron by dif.....	11.50 "
Silicon	1.65 "
Phosphorus	0.23 "
Carbon	6.78 "
Sulphur	 "

It is sold per ton, 2,240 pounds.

Ferro-Molybdenum.

Ferro-molybdenum is sold per pound of pure molybdenum contained, regardless of the percentage of other material. Thus, if a pound of 80 per cent. ferro-molybdenum is purchased, $1\frac{1}{4}$ pounds of the alloy will be received. A typical analysis, the units of molybdenum only guaranteed, is as follows:

Molybdenum	79.15 per cent.
Iron	17.55 "
Carbon	3.24 "
Phosphorus	0.028 "
Sulphur	0.021 "

Ferro-Nickel.

As ordinarily used in steel this is guaranteed over 99 per cent. nickel and is sold by the pound.

Ferro-nickel is also supplied with 25, 35, 50 or 75 per cent. of nickel as specified. The balance of analysis outside of the nickel and iron runs about:

Carbon	0.85 per cent.
Silicon	0.25 "
Sulphur	0.015 "
Phosphorus	0.025 "

Ferro-Phosphorus.

Ferro-phosphorus contains over 10 per cent. of phosphorus. The foreign is guaranteed 22 to 24 per cent. phosphorus.

A typical analysis of foreign, the phosphorus alone being guaranteed, is as follows:

Phosphorus	21.40 per cent.
Iron	75.03 "
Manganese	0.70 "
Silicon	1.63 "
Carbon	1.17 "

The domestic is guaranteed:

Phosphorus	18 to 22 per cent.
Sulphur	under 0.05 "
Manganese	under 0.50 "

It is sold per ton, 2,240 pounds.

Phosphor-Manganese.

A typical analysis is:

Manganese	65.00 per cent.
Phosphorus	25.00 "
Iron	7.00 "
Carbon	2.00 "
Silicon	1.00 "

Silico-Spiegel.

Silico-Spiegel contains manganese 17 to 22 per cent. and silicon 6 to 12 per cent. The standard is guaranteed as follows:

Manganese	18 to 20 per cent.
Silicon, 9 to 11 per cent.....	average 10 "

A typical analysis, nothing but manganese and silicon guaranteed, is as follows:

Manganese	20.32	per cent.
Iron by dif.....	68.02	"
Silicon	10.33	"
Carbon	1.25	"
Phosphorus	0.07	"
Sulphur .....	....	"

It is sold per ton, 2,240 pounds.

Ferro-Silicon.

Special High Silicon contains over 40 per cent. silicon. It is guaranteed 50 per cent. silicon, with an allowance of \$1.75 per unit either way. The other elements are not guaranteed. A typical analysis is:

Silicon	49.90	per cent.
Manganese	0.16	"
Carbon	0.55	"
Phosphorus	0.075	"
Sulphur	0.018	"

It is also guaranteed 75 per cent. silicon, with an allowance of \$2.50 per unit either way. It is sold per ton, 2,240 pounds.

Bessemer Ferro-Silicon.

This runs 8 to 16 per cent. in silicon, the price usually increasing or decreasing \$1 per unit.

The "Domestic" is guaranteed silicon as specified 8 to 16 per cent.

Phosphorus	not over 0.10	per cent.
Sulphur	not over 0.05	"

The "Foreign" is not guaranteed, but phosphorus and sulphur, while not guaranteed, run very low. It is sold per ton 2,240 pounds. For lower percentages of silicon, see "High Silicon Irons."

Ferro-Sodium.

Ferro-Sodium is usually sold with 25 per cent. metallic sodium and free from lime or excess of carbon.

Spiegel-Eisen.

Spiegel, Spiegel-Eisen or Mirror Iron contains 10 to 40 per cent. of manganese. The standard is guaranteed:

	Per cent.
Manganese, 18 to 22 per cent.....	average 20
Phosphorus	0.10 or under

The silicon limits are sometimes specified, as it is desirable to know how the same will run. A typical analysis, only guaranteed as above, is as follows:

Manganese	20.50 per cent.
Iron	73.61 "
Silicon	0.76 "
Carbon	5.18 "
Sulphur	0.002 "
Phosphorus	0.055 "

It is sold per ton, 2,240 pounds.

Ferro-Titanium.

The lower titanium contents is sold guaranteed only in titanium, which is 10 to 12 per cent., and is sold by the pound of alloy.

A typical analysis is:

Titanium	11.21 per cent.
Iron by dif.....	87.68 "
Carbon	0.67 "
Silicon	0.37 "
Phosphorus	0.04 "
Sulphur	0.03 "

If higher in titanium, it is sold per pound of pure titanium contained, regardless of the percentage of other material, the titanium above being specified. A typical analysis is as follows:

Titanium	51.30 per cent.
Iron	44.18 "
Carbon	2.82 "
Manganese	0.14 "
Arsenic	1.10 "
Sulphur	0.04 "
Phosphorus	0.021 "
Aluminum	0.41 "

Ferro-Tungsten.

Ferro-Tungsten is sold per pound per unit of tungsten contained, the price increasing with the increase in tungsten and decreasing with the increase in carbon. A typical analysis, the tungsten and carbon only being guaranteed, is as follows:

Tungsten	85.47 per cent.	61.20 per cent.
Iron	13.90 "	33.02 "
Carbon	0.30 "	2.97 "
Silicon	0.13 "	0.47 "
Manganese	0.09 "	1.88 "
Aluminum	0.00 "	0.31 "
Phosphorus	0.019 "	0.03 "
Sulphur	0.025 "	0.03 "

Ferro-Vanadium.

Ferro-Vanadium is sold per pound at price per unit of vanadium contained; that is, if alloy contains 20 per cent. vanadium and selling price is five cents per unit, it would cost \$1 per pound of alloy. A typical analysis as made by one foreign company, vanadium alone being guaranteed, is as follows:

Vanadium	36.0 per cent.
Manganese	0.6 "
Iron	61.0 "
Carbon	0.4 "
Silicon	0.9 "
Aluminum	0.8 "

Typical Analysis of Mayari Iron.

Silicon	0.85 per cent.
Phosphorus	0.055 "
Sulphur	0.018 "
Manganese	0.97 "
Chromium	2.61 "
Nickel	1.49 "

It will be noticed that all the foregoing analyses of ferro-alloys show them to be very highly alloyed with the iron; in fact, most of them are so highly alloyed that the characteristics of both the iron and alloy metal are completely destroyed. Many of these alloy metals have no affinity for cast iron, and cannot be combined with it in a pure state; and if the alloy is so high that it completely destroys the iron, then what chance is there for having the ferro-alloy absorbed by iron, either in a cupola or ladle. I cannot see that there is any, except by the use of a powerful flux, that will create an affinity between the iron and the ferro-alloy. Such a flux has not been supplied by the manufacturers of ferro-

alloys, and the result has been that no benefit has been derived by foundrymen from the use of ferro-alloys of any kind, either in cupola or ladle, although there are foundrymen who have such great faith in ferro-alloy that they think they cannot get along without them. A manager of one of the largest foundries in the country that I met two years ago, when manganese was selling at four to five hundred dollars per ton, and could not be had even at that price, stated that they had been using ferro-manganese for years, and thought they could not get along without it, but when they were unable to get it and had been compelled to run without it for two months, they did not find any difference in the iron, and the ferro-manganese had been of no benefit to them.

I have tested many of the high ferro-alloys in both cupola and ladles, sprinkled them into the stream as it flowed from the cupola, stirred them into the molten iron, placed them in the bottom of ladles, etc.; but have never been able to improve the iron to an extent that warranted the expense of the ferro-alloys, and I believe that metals and elements can only be combined with cast iron by certain undetermined native conditions, which place them in combination with the iron in its ores. This is shown in Mayari iron, which contains two metals that cannot be combined with cast iron by any known process. It will be noticed that neither of these metals or any of the other metalloids are sufficiently high to destroy the iron, which leaves the iron as the controlling metal, and it unites freely with other irons and imparts these alloy qualities to the mixture in a modified form or per cent. The same is the case with all low ferro-alloys.

All foundry pig irons are, practically speaking, a low ferro-alloy, in which the alloy does not destroy the iron or prevent it mixing freely with other irons and imparting its alloy qualities to it as pig or scrap. As foundry pig may be obtained, containing a per cent of any desired metalloid, far above that required for any line of castings, I can see no reason why any iron founder should purchase or use a higher ferro-alloy than that he can obtain in combination with the iron in his pig.

If the mixture is low in silicon and castings running hard, place a high silicon pig in the mixture to bring the silicon up to a point that increases graphite carbon and gives a soft iron. If manganese is low in the mixture, increase manganese by placing a higher manganese pig in the mixture. When phosphorus is low, place a higher phosphoric pig in the mixture. In this way, any desired metalloid in a mixture may be increased in a more effective manner than by the use of a high ferro-alloy; and they may be decreased by placing a lower alloy pig in the mixture.

Testing Irons

CHAPTER VIII.

Definition of Test.

The term "test" as applied to cast iron means the subjecting of the iron to such conditions as will disclose its true character and indicate its stability for the work to be cast from the quality or grade of it tested. This may be done by chemical analysis, the characteristics of the iron before it is cast being indicated by determining the per cent. of various metalloids it may contain, the effect of these metalloids upon it being such as to give to it certain characteristics that are known. Or, by physical tests, which means the subjecting of the iron after it has been cast to such tests as will disclose its physical characteristics and indicate whether it is suitable for the work to be cast. These characteristics are appearance of grain in fracture, shrinkage, depth of chill, hardness, softness, strength, change of shape while under stress, etc.

Physical tests are made by means of test bars which, when subjected to various tests, indicate the characteristics of the iron as follows: Shrinkage test indicates the extent to which iron contracts in cooling from its length when hot. This test is made by casting a test bar of a given length and determining the extent it shrinks by comparison with the pattern from which it was moulded. To insure accuracy in this test some means must be provided to prevent the sand at the end of the bar being forced back by the molten iron and the test bar from being longer than the pattern. This is done by a cast iron yoke, against which the ends of the bar are cast, an exact length of the pattern being thus insured. This test is of value in determining the length and size the pattern should be made to insure a casting of a given length or

size, and also in determining whether castings that are to be assimilated, as in stove plate, will be of a proper size if cast from different brands of iron.

Fracture Test.

By fracture is meant the breaking of a piece of iron or test bar and judging the quality of the iron from the appearance of the fresh fracture, which is indicated by the size of the crystals, the luster, chilling tendency, etc. This test indicates the hardness or softness of the iron as the crystals are large or small. A large crystal with a dark luster is evidence of a soft iron, a small crystal and light luster of a harder iron, and a white crystal of a very hard iron. A white outer edge indicates the tendency of the iron to chill, and that it is too hard for very thin castings. Fracture also indicates to some extent the strength of iron, a sharp pointed crystal being evidence of a stronger iron and a dull crystal of a weaker iron.

Transverse Test.

Transverse Test is the breaking of a bar of iron under a known weight, and is made by supporting a test bar at each end and applying an increasing pressure or weight to the center of the bar until it breaks and recording the number of pounds required to break it. Cross breaking is the most common break in cast iron, and this test, together with deflection or bending of the bar before breaking, is considered the most important test of cast iron.

Change of Shape.

By change of shape under strain is meant the deflection or bending of a test bar before breaking. This is carefully measured, and indicates the extent to which the iron is likely to give or bend in a casting before breaking when subject to strain.

Tensile Test.

By this test is meant the pulling or drawing apart of a piece of iron or test bar. This test is considered of little importance for cast iron, it being seldom subject to this strain in actual use. It is a very difficult test to make accurately, owing to the difficulty in holding the test piece in the testing machine so as to place an even strain on all parts of it, and is seldom used for cast iron except

in foundries where cylinders are cast for steam pumps, hydraulics, etc.

Impact Test.

Impact Test means the breaking of a piece of iron by a blow and recording the number and weight of blows required to break it, and also observing the condition of the test-piece after each blow, as to whether it is battered, chipped off, cracked or broken. Little attention is given to this test, which can only be accurately made in a machine constructed for the purpose and by an expert. Foundrymen usually make it with an ordinary hammer or sledge and judge the quality of the iron by the weight of the hammer or sledge and the number of blows required to break it and its condition after breaking.

Crushing Test.

Crushing Test means the placing of sufficient weight upon a short cylinder or square piece of iron to crush it. This test is of little value to the founder and the weight or stress required to make it is so great that it is not often applied.

Direct Physical Test.

This means the breaking of a casting, an exact duplicate of a cast from the same iron whose strength and other qualities it is desired to learn. This test is only of value when a large number of castings are cast from the same pattern.

Relative Test.

All tests are relative tests, for it is only by comparison with a standard test, which means the greatest amount of desired quality in an iron, that any conclusion can be drawn as to the quality of iron being tested.

Standard Test.

The standard test may be that designated by scientists for the various tests and mean the best results they were able to obtain under the most favorable conditions in a testing laboratory, or it may be the best results the tester himself has been able to obtain. The latter will generally be found to be the most satisfactory, for there are elements such as hardness, softness, shrinkage, etc., which must be considered in the production of each line of castings that were probably not kept in view by the scientist

making the established test, his only aim being to obtain the best results from material tested.

Standard Foundry Test.

This is a test that shows the best results that have been obtained in all the qualities desired in the line of castings to be made. It may include one or more methods of testing, each of which has a standard such as standards of strength, softness, shrinkage, hardness, chill, etc., which, when combined with each other, in a test-bar or piece, indicate the quality of iron desired in work to be cast.

Chilled Test.

By chilled test is meant the tendency of molten iron to chill when run against a cold iron and suddenly cooled. This test is made by moulding a piece the thickness and shape of the part of a casting to be chilled and forming the side or a part of the mould with a chill the thickness of the one to be used for chilling the casting and filling the mould with the quality of iron to be used for the chilled casting. This test-piece when broken shows the depth of chill, the extent to which the chilled fibers extend into the soft iron, resistance to shock, etc. This test is of value in making chilled castings, such as car wheels, crusher-jaws, plows, plow-points, etc.

Test Bars.

Owing to the variation in strength of test bars, it is generally considered that one bar does not fairly represent the actual strength of the iron, and it is the practice to cast three or more bars of each size, test them and take the average breaking strength of the bars as indicating the actual strength of the iron cast. When it is only desired to learn the strength of iron cast in a certain part of a heat, these bars may all be cast from one ladle. But if it is desired to learn the strength of iron throughout the entire heat, they must be cast from different parts of the heat and may be cast singly or in pairs. As these bars are made for comparison with each other, it is very important that they should be of exactly the same size, for a large bar shows a greater strength than a small one, even when the difference in size is so small that it cannot be detected by the eye. It is therefore absolutely necessary that the greatest of care should be taken in making patterns and in moulding. Iron patterns are the best, for they are more stable than wooden ones, which are liable to shrink.

when not in use, and when placed in damp sand or wet in sponging, expand to such an extent that the second bar, moulded from the pattern, may be larger than the first one. If the bar is to be broken in the center it should be gated at the end, and every bar should be gated in the same way and have the same size gate. It is good practice to use a set gate. Care should be taken to not wrap one bar in moulding more than another, and to have the temper of the moulding sand the same for each bar. Special care should be taken to ram each bar evenly throughout its length and ram all bars to give the same degree of hardness to the mould.

It is good practice to have all the bars moulded by the same moulder. The iron should be carefully skimmed before pouring, and all the bars should be cast with iron of as near the same temperature as possible. When bars are cast from different parts of a heat they should be moulded in separate flasks, for the pouring of one or more bars in the same flask dries out the sand and causes each succeeding bar to be heavier, strained, etc.

Length of Test Bars.

Test bars may be cast of any length that suits the fancy of the tester, but for transverse tests they are generally cast 12 or 24 inches long. Twelve inches is the most common length and testing machines are generally constructed for this length, it being also best for comparison with standard tests, which are generally made with the twelve-inch bar. By the latter is always understood twelve inches between the bearings upon which the bar is placed for testing, and the bars are generally cast twelve and a half or thirteen inches long, and are sometimes sixteen inches. This is done to test the iron farther from the gate, but there is no special advantage in this, and it is just as well to cast them only long enough to give a proper bearing upon the testing machine.

Care in Casting Test Bars.

Cast iron is such a complex body that its strength and general characteristics may by the manner of manipulation be changed to such an extent as to have test bars indicate a totally different grade of iron from the one actually cast for testing. These changes are to a large extent under the control of the founder and moulder, and should be duly considered in making a few test bars that are designed to indicate the strength and quality of iron in a heat of many tons of castings. By cooling iron rapidly, the size of the crystal and general appearance of the fresh fracture are entirely changed from those of a test bar of the same size cooled

slowly and the strength of the bar is less. Hence the importance of casting bar for comparative tests in sand of the same temper so that one bar may not be cooled more rapidly than another by wet sand. Bars should never be shaken out when red-hot, and each bar should be permitted to remain in the sand about the same length of time as another. It is not good practice to let the bars remain in the sand over night to be annealed by the hot sand unless the castings are permitted to remain in the mould over night. The temperature at which the iron is poured also greatly affects the strength of iron, and we may cast two bars from the same ladle of iron and have them show a wide difference in strength by pouring one with very hot iron and the other with dull iron. Some irons give a stronger bar when poured hot and others when poured dull, so that no definite temperature for pouring to obtain the strongest bar, that will apply to all irons, can be stated. But as the strength of the bars is for comparison with each other and to indicate strength of iron in castings, they should all be poured as near the same temperature as possible and as near that of the iron for pouring the castings as possible. The part of the heat from which iron for test bars is taken is another important matter. The first iron melted is always hardened to a greater or less extent by moisture in the sand bottom, by a damp spout, cold ladles, etc., and does not fairly represent the quality of the metal. From five to twenty hundredweight of iron, according to the size of cupola and heat, should be poured before test bars are cast.

Iron is hardened by boiling in a green ladle, and chilled to an extent that makes the grain closer, by a cold ladle. A hot ladle should therefore always be used for casting test bars.

Tensile and Other Test Pieces.

Tensile bars or pieces are made of a size and shape to fit the testing machine in which they are to be drawn. They, as well as all other test pieces, whether for strength, chill, or drilled tests, should be cast with the same care, for they are designed to indicate the quality of iron in the castings and should be cast under as near the same conditions as possible.

Strength of Cast Iron.

The strongest part of cast iron is generally considered to be in the outer surface of the iron or casting, and the cutting away of this reduces the strength of the iron. This is due to the outer surface being cooled more rapidly than the center and graphite,

carbon, sulphur, etc., segregating to the center as the iron changes from a molten to a solid state. But this does not apply to all irons or castings, for very thin castings cooled quickly throughout show about the same structure or size of crystal at the center as at the outer edge, and the removal of the outer scale reduces the strength only to an extent corresponding to the reduction in size of the iron. Then again, irons that do not contain an excess of the segregating elements are not weakened to the same extent by the cutting away of the outer surface as those that do, and this weakness is not apparent in a close iron to the same extent as in a soft, open one. The cutting away of the mere casting or skin scale has very little effect upon the strength of the iron, for it does not lie in the scale but in the structure of the iron beneath it. This structure changes in heavy castings from the outer surface inwardly and, as it nears the center, the crystals become larger and the iron more open, and weaker. Hence the greater the amount of the outer surface cut away, the less the strength of the iron will be. Civil engineers and others who have learned that the greatest strength of cast iron lies in its outer surface have attempted to obtain an extra-strong iron in their castings by having test bars made from the iron used for them. To do this they have required test bars four inches square, or two by four inches, to be furnished with the castings, and from the center of these bars have cut a one-inch square bar for the test, and required this bar to show the strength called for in the specifications for the castings. This test is unfair to the founder, for it is made from the very weakest part of the iron, and were he required to give the specified strength for the casting in this part of the iron, he would have to far exceed the strength of cast iron.

It was this kind of trickery, not only by private firms but by government officials also, that induced the Foundrymen's Associations to take up the matter of testing and endeavor to establish a standard test for the various grades of castings. By doing so it was hoped to establish a standard that will be fair to both parties, and not admit of a founder being required to furnish castings of a strength above that of cast iron. To fairly represent the strength of iron in a casting a test bar should be cast of the same thickness as the casting, and tested without removing the outer surface of the bar.

Adding Strength to Cast Iron.

The strength of cast iron may be increased to almost any desired extent by adding steel to it when melting in a cupola. In

doing this, care must be taken to select an iron that will absorb the steel without being hardened by it to so great an extent as to make it unfit for the work to be cast. This is controlled by the per cent. of silicon the iron contains. A high-silicon iron carries a larger per cent. of steel than a low one without hardening. The casting of a few test bars for a mixture of steel and iron in the yard will determine the per cent. of steel to be melted in the mixture. When making mixtures of this kind, for strength specifications, care must be taken to not exceed the strength of cast iron. A founder who resorted to this means of bringing his iron up to the strength called for in a government contract, succeeded in obtaining a transverse strength of 4500 lbs. in a $I \times I$ bar, and had the casting condemned for the reason that it exceeded the strength of cast iron, and therefore was not cast iron, as called for in the specifications.

Wrought iron also increases the strength of cast iron when melted with it. In making this mixture, the per cent. of wrought iron used, like the per cent. of steel, is controlled by the per cent. of silicon the iron contains. But as the object sought for is a strong iron, the silicon should be as low as possible to insure a soft casting, and in this case, the wrought iron should not exceed 30 per cent. This mixture, as well as that with steel, should be melted very hot to insure an even mixture of iron, and sound castings.

Cast iron may also to some extent be strengthened by adding wrought iron or steel drillings, and turnings to the iron in a ladle. But this is a very unsatisfactory process, for the heat absorbed from the iron in melting the turnings is so great that the iron becomes dull so rapidly that only a very limited amount can be added. If the turnings are not thoroughly absorbed into the iron they cause blow-holes, and the least excess of borings makes it difficult to get a sound casting. A better way of adding wrought iron or steel to iron in a ladle is to heat a bar in a forge to a white heat, and place it in the iron, or stir it with it. It is then mixed with the iron as it melts off the bar, and the excess is removed when the bar is withdrawn. This insures a more even and sound casting, as the bar can be removed when the iron is at a proper temperature for pouring.

Annealing increases the strength of a close, hard iron, but lessens that of a soft, open iron.

A low-silicon iron generally produces a stronger casting than a high-silicon iron.

By varying the proportions of different irons in a mixture, a stronger iron can sometimes be produced from the same iron. The larger the per cent. of No. 2 iron in a pig mixture, the stronger the castings as a rule will be.

A good grade of scrap added to an all-pig mixture invariably increases the strength of castings. About 50 per cent. should be added for this purpose.

Testing Machines.

A home-made testing machine may be constructed in various ways at a very small cost. But such machines are only make-shifts at best, and require a great deal of time and labor in manipulating, and frequently do not accurately indicate the strength, hardness, softness or shrinkage of the iron; and it is better to buy a standard testing machine or send bars to a testing laboratory to be tested.

One of the best machines manufactured for light castings is that of W. J. Keep, Detroit, Mich. This machine, or rather system of testing, indicates very accurately the strength, deflection, shrinkage and chilling tendency of a half-inch square test bar. It is very highly spoken of by foundrymen making stove plate and light castings. Mr. Keep also makes a drill-testing machine for testing hardness for heavier work that indicates very accurately the hardness of iron.

For heavy work probably the best testing machines are those manufactured by Riehle Bros. Testing Machine Co., Philadelphia, Pa. This firm makes a line of testing machines suitable for all the various tests required in specifications for castings, and for the one-inch square transverse test. Their machine is probably the most convenient in use for a general test.

Standard for Strength.

There is practically no standard of strength for cast iron, for the transverse and tensile strength of cast iron varies with the per cent. of the various metalloids it contains, to an extent that in the one-inch square test bars, twelve inches between bearings the strength has been found to vary from five hundred pounds to twenty-eight hundred pounds to the square inch, and a corresponding variation has been found in the various grades of cast iron, but also in the same grade, for rarely do two test bars, cast from the same ladle of iron, show the same breaking

strength. Only by taking the average of two or more bars, can a standard for strength be established for any line of castings. The weakest irons are the high silicon irons and some of the white irons, but all white irons are not weak irons.

A close iron in a one-inch test bar is generally a strong iron, that runs soft and strong in heavy castings, but hard and weak in light castings. A soft, open iron in a one-inch bar is generally a weak iron, that runs too open and weak for heavy castings, but runs close, soft and strong in light castings.

This shows the importance of having the size of test bar as near the thickness of the castings as possible, if the strength of the test bar is to indicate the strength of the iron in the casting. If the deflection or bending properties of the iron in the casting are an important factor, the length of the test bar is also an important matter.

The stove foundries have generally adopted the J. W. Keep test bar system, with a half-inch square bar cast in a yoke, that indicates shrinkage as well as strength. Many of them also use a test bar one-eighth-inch in thickness, one to two inches wide, and twelve to twenty inches long. This bar is gated at one end and is designed to indicate the flowing properties of the iron, the distance it will run without showing a chilled edge, and the deflection of the plate.

Jobbing and machinery foundries generally use a one-inch square or round bar of a length to give twelve inches between bearings. This is regarded as a standard size test bar for many lines of castings. Government and other specifications for castings frequently require this bar to be cast upon the casting and will not accept a separately cast test bar from the same iron.

For heavy castings, test bars are frequently required to correspond to some extent to the thickness of the casting, and vary from one to four inches square and one to four feet in length. For deflection tests, bars are cast from one to six feet long, and of a thickness to correspond to the thickness of casting.

The following table will give the average strength of a good machinable cast iron that may be found in test bars of different sizes, twelve inches in length:

Transverse Test Bars in Green Sand and not Machined.

Approx. Cross Sections. Inches.	Actual Size.		Breaking Strain. Lbs.	Deflection. Inches.
	Depth. Inches.	Width. Inches.		
.5 x .5	.53	.57	.380	.190
	.52	.53	.320	.200
	.54	.56	.460	.210
	.54	.55	.340	.190
1 x 1	1.04	1.04	2.140	.130
	1.01	1.03	2.580	.110
1.5 x 1.5	1.52	1.52	8.060	.102
	1.57	1.53	7.920	.102
2 x 2	2.03	2.04	16.180	.101
	2.01	2.03	14.920	.087
2.5 x 2.5	2.57	2.59	30.500	.103
	2.51	2.50	27.680	.101
3 x 3	3.03	3.02	45.790	.099
	3.03	3.02	45.660	.102
3.5 x 3.5	3.52	3.54	68.470	.091
	3.57	3.56	70.140	.092
4 x 4	4.00	4.06	over 100.000	
	4.02	4.05	over 100.000	

The Shore Scleroscope.

The Shore Scleroscope is an instrument designed to indicate and register the hardness and evenness in metals whether hot or cold. This instrument consists of a drop weight or hammer of hard steel with a very sharp point, placed between two graded slides or guides, to be dropped from various heights upon the tested metal, and a dial indicates the depth to which the point has penetrated. The metal is moved after each drop of the weight and the depth to which the point penetrates indicates the hardness of the metal, and by moving the metal and striking it at different points, hard points in castings may be detected.

Many of the automobile and other plants making specialties for which special tools are used in finishing, require this test to be made to avoid destroying their tools by running into a hard spot in high speed machining. This testing instrument costs considerable money, and is of little value to a grey iron foundryman except for special castings, and in many cases where this

test is specified, foundrymen have required the contracting parties to furnish the testing instrument or to do this testing at their own plant.

Full details, price, etc., of this instrument, for which the following claims are made, may be obtained from Shore Instrument and Manufacturing Co., Inc., 555-557 West 22d Street, New York City.

What They Use the Scleroscope For.

No. 1—To measure the hardness of all metals generally.

No. 2—To measure the hardness of carbon.

No. 3.—To show if the grain in hardened steel is fine or coarse.

No. 4.—To measure the red hardness and cutting rates in high speed steel.

No. 5—To show whether or not steel is annealed enough to permit machining with profit.

No. 6—As a check on the pyrometer, in heat treatment of steel.

No. 7—To test the hardening qualities of tool steels and automobile steels when heat treated.

No. 8—To show if in case hardened parts the cementing heat has been high enough to crystallize and render same too brittle.

No. 9—To determine carbon content in mild steel and carbon tool steel.

No. 10—To determine the tin content in bronze.

No. 11—To detect segregation in any alloy.

No. 12—In metallography, in connection with the microscope to test the correctness of visual analysis both in homogeneous and segregated metals.

No. 13—As a guide in any foundry where metals of a uniform quality are to be produced either in finished castings or ingots for the market.

No. 14—As a guide in experiments with view to the ultimate production of new alloys in any metal (ferrous or non-ferrous) the slightest change in hardness due to the addition or subtraction of any element is thus measured and recorded.

No. 15—In rolling mills, to find the heat most suitable during the finish rolling passes for a particular kind of steel so that it will give the greatest strength for structural purposes, rails, etc., or the best qualities when it is a tool or automobile steel to be hardened. In hammering and forging likewise.

No. 16—What hardness an ingot must show to be relied on to yield a given and prescribed hardness in the wire, rod, plate sheet, bar or tube, particularly when more or less annealing afterward cannot be resorted to or as when high hardnesses are required.

No. 17—In chilled rolls, etc., just what hardness a certain grade of metal will develop when chilled more or less, thus allowing rectification beforehand.

No. 18—In cold working of metals, particularly steel, it is not alone enough to be able to produce dies, rolls, etc., of the highest quality but the stock to be worked must be tested to eliminate material which will show hardness high enough to ruin expensive tools.

No. 19—In springs for typewriters, electrical mechanisms, etc., which are made of cold rolled steel or bronze, the requisite elasticity is indicated by a given hardness number.

No. 20—In springs of steel to be heat treated as for vehicles, railway cars, air brakes and machinery, a certain uniform heat treatment should produce a uniform temper provided the raw material is of the necessary uniform grade. This latter is obtained by sorting out the unsuitable grades by aid of the scleroscope.

No. 21—In boiler making to test the malleability of the tube ends before expanding into the plates. Some governments have traced leaks and explosions due to lack of attention to the subject, and who now regularly use the scleroscope to guard against this danger.

No. 22—In steel making, to determine carbon content in a few minutes before pouring the metal.

No. 23—To measure the strength of soft and hardened steels or each part used commonly in motor car work by observing certain other conditions, and which otherwise can only be determined in one master test piece but not on each finished part.

No. 24—To test finished tools as particularly milling cutters, reamers, punches and dies, etc., when they are to be reliable.

No. 25—To detect deterioration in high speed steel due to over-soaking in the fire.

No. 25a—To order material to specification.

No. 26—To test material before selecting to purchase.

No. 27—To test war material as armor plate, projectiles and gun metals.

No. 28—To test the hardness of rivets to avoid the danger of their shearing as when too soft.

No. 29—To demonstrate to college students the effects of the heat treatment on all metals as well as the effect of mechanical operations.

No. 30—In hardening chrome nickel steel it is found that there is a wide variation, while yet it is important that the finished parts all be of the same prescribed hardness. This is obtained by sorting out the parts in lots showing the different degrees of hardness by aid of the scleroscope. Each lot is then reheated more or less as required to bring them all down to the same hardness. Some, thus may not have to be reheated at all, while others must be rehardened or carbonized to permit the proper hardening.

No. 31—In making tools of high speed steel to be used on tough but soft material and which must resist high torsional strains the best results are obtained at a fixed and prescribed hardness after tempering, regardless of the original hardness shown. Here also the tempering heat must be more or less as the original hardness varies to insure the said uniform specified hardness.

No. 32—To study the depth of hardening in steels intended for high pressure dies to avoid failures due to fracturing or sagging of the engraved surfaces.

No. 33—In tempering baths, to show what heat is required to produce a prescribed hardness in any metal subject to this treatment.

No. 34—As a code between the engineer and draughtsmen who can at last understand each other on the various hardnesses of the metals to be used for each part.

No. 35—As a code between the draughtsmen and the shop staff who can at last understand each other perfectly as to the conditions of the material required for each part.

No. 36—To study up shop conditions with reference to the most suitable conditions of the tools and also the metals worked with them for the purpose of establishing economy standards and systematization of practice. This is the most common tendency and is vitally important.

No. 37—As a ready guide for workmen who are professional hardeners or persons who must frequently do work of this class.

No. 38—To inspect material to be worked up in automatic metal working machines as screw machines, etc., when a hard piece will often render these machines inoperative until readjusted. The usefulness and economy of these machines have thus been greatly extended.

No. 39.—To measure depth of case-hardened work by testing the bottom of a small nick ground in an unimportant part thereof; this method also shows the hardness of the core, which is vitally important. The hydraulic pressure scheme sometimes recommended is comparatively unreliable.

Perfect Castings

CHAPTER IX

Dirt in Castings.

Dirt in castings may be due to a number of causes, among them dirt or slag in the iron, a dirty mould, poor skimming, bad pouring, poor moulding sand, poor cores, dull iron, bad melting, etc.

Dirty iron was a very common complaint in the days of mill sinder. Mill sinder is a slag that is drawn from the puddling furnaces of rolling mills in which cast iron is puddled until all the carbon and other impurities are burned out of the iron, and it can be formed into balls for the squeezer and muck rolls. This slag contains a high per cent. of iron, and was smelted in blast furnaces to recover the iron. This mill sinder, as it is called, frequently produced a pig iron that run very dirty when remelted for foundry work. But the rolling mills for wrought iron have almost disappeared and with them mill sinder, but there is still a limited amount of sinder from mills and various iron and steel plants smelted in blast furnaces. There are also mixtures of ores that do not unite to produce a clean foundry iron, and a furnace working hot and cold sometimes produce a dirty iron, so that there is still a possibility of dirty iron when remelted and cast.

When dirt or blow holes are found in castings the first thing to be done is to look to the melting of the iron, and see that it is melted hot, and of an even temperature throughout a heat. A dull, uneven melted iron is often the cause of dirt in castings. The next thing to do is to look after the pouring and see that the iron is properly skimmed; that the gate is kept well filled in

pouring; that a steady stream made to flow into the mould and fill its quickly. The size of the gate should be looked after. See that it is a proper size for the casting and correctly located. If these precautions do not prevent the appearance of the dirt, the casting should be carefully inspected to see that there is no scabs on it, no sharp corners or projections of the mould washed away, and that it is a perfect casting on the outside. If a cored casting, the inside should also be carefully inspected to see that the core has not cut or washed, and it is also well to look to the core blackening, for a cheap core wash put on too thick to make sand peel, may be the cause of a dirty casting by washing before the iron. When there is only trouble with one or more special castings, it is a good plan to give the pattern to another moulder and also change the core maker, core mixture or binder. When all these remedies fail the dirt must be in the iron, and the best thing to do is to use Kirk's Cupola and Ladle Compound, which has been in use by foundrymen for the past forty-five years as a cleanser of iron.

I was recently called upon to investigate the cause of dirt in a lot of castings. The castings were comparatively heavy hydraulic castings, required to be close strong iron, that would not sweat, and be perfectly clean and free from blow holes. I found that the iron was not being melted sufficiently hot for the castings, and the mixture of iron was too open and porous. The condemned castings, that were perfect on the outside, when broken and the inside inspected, showed that the dirt in the casting had come from the core. The core had evidently been slicked down with the trowel until it was too low in the box at one point, and to bring it up to a proper size sand had been thrown on the slick surface and slicked again with the trowel. It could be plainly seen that part of this sand had been washed away by the iron, giving an extra thickness in the casting, and leaving a ragged edge and offset in the cored surface of the casting. This showed where the dirt had come from and the attention of the core maker was called to it. An extra basket of coke on the bed for each charge and the addition of 20 per cent. of steel to the mixture gave a perfectly clean close iron in this case. From 10 to 20 per cent. steel should always be placed in mixtures for hydraulic steam and ice machinery castings to close up the iron and prevent sweating.

Sandwich Hard Spots.

A sandwich hard spot in a casting is a white very hard iron that does not extend fibers into the soft iron by which it is sur-

rounded, but lays as separate and distinct between the plates of soft iron as a slice of ham between two slices of bread.

This iron flows as freely as the soft iron with which it is melted, and large patches of it may be found in the center of a thin plate only one-eighth of an inch in thickness, between two plates of very soft iron, but not at all attached to either plate. In heavier castings when diffused through the iron, it forms in small nodules which have no connection with the soft iron. When a casting is broken at the point where they are imbedded, they frequently fall out of the soft iron.

This kind of a hard spot was quite prevalent in the eastern section of this country about forty years ago, and foundrymen were very much annoyed with them. I first met with these spots at Albany, N. Y., in 1876. At that time the stove foundries of Albany and the east were melting as their principal iron, Lehigh Valley Pig of various brands, which had proven very satisfactory for a number of years. When the sandwich spots appeared they were attributed to other pig in the mixture and one brand after another was condemned as a hoodoo iron. At that time I made my first visit to Albany, N. Y., selling my cupola and ladle compound. As the stove founders were all having trouble with their iron, I found them like the captain at sea in a storm, willing to run into any port to get out of the storm, and had no trouble in inducing them to give my compound a trial.

Tests were first made with their regular mixture and some improvement made, but the hard spots were not entirely eliminated. The fracture of their No. 1 pig presented the appearance of a very soft open iron, with an even crystalline structure that gave no indication of hard spots, but there was something about it which I could not explain but I did not like, and I suggested that the No. 1 in the mixture be decreased and the No. 2 increased. This was done and gave a more even soft iron. I then suggested that they eliminate the No. 1 iron entirely and replace it with one of the hoodoo irons. This was such a radical change that I was only able to induce them to make one small charge on the bed, which proved so satisfactory that they were willing to try a full heat, and only a few years ago another Albany foundryman told me of Colonel Young, the then foreman of Rathbone, Sard & Co., coming to him and getting all the hoodoo iron he had, to stick me in this proposition, but the test proved perfectly satisfactory. Similar tests were made at the foundry of The Perry Stove Co. and several other foundries at Albany and Troy, and the hoodoo iron, which was an iron

made at the furnace on the island at the lower end of Albany, was returned to its normal state.

From these tests I received enough money to publish my first work on foundry practice, entitled "The Founding of Metals," which was printed by Charles Van Benthuysen & Sons, printing and binding company of Albany, N. Y., in the winter of 1876-7, and was given the credit by the late Thomas D. West of being the first practical work ever published in this country or any other on foundry practice.

The stereotype plate for this work, after the publication of numerous editions, were destroyed by fire in New York City and the work has long been out of print. A curious thing about these tests was that the Lehigh Valley No. 1 pig, which was supposed to be the best iron in the mixture, was really the hoodoo iron, and contained the sandwiched hard spots to a far greater extent than the No. 2 of the same furnace. This hardness, after these tests and a report of them to the furnacemen of the Lehigh Valley, were found by their chemist to be due to a New Jersey iron ore which had been placed in their ore mixture with a view or reducing the cots of their iron, and the discontinuance of its use completely restored this iron to its former good quality.

I have never found these hard spots where they could be traced to the pig iron except in the case above stated, but have occasionally found them in very soft castings in which burned scrap was melted in the mixture, and as they did not appear continuously, day after day, I attributed them to the badly burned iron in the mixture, and to avoid them would advise throwing all burned scrap out of a mixture for very soft castings, and also avoid melting badly rusted shot iron in soft mixtures.

Blow Holes in Castings.

When blow holes, small or large, are found in castings, they are frequently blamed upon the iron, and in fact more often attributed to the iron than any other cause. This is a mistake, for very rarely does an iron when properly melted and poured hot contain blow holes when cold, and blow holes in castings are more frequently due to agitation of the iron at the moment of solidification than from gases in the iron.

When blow hole trouble occurs the first thing to be done is to look to the temperature of the sand and the ramming of the mould. Molten iron does not lay quietly against a wet or hard rammed sand but boils and bubbles, and the bubbles are retained in the casting as blow holes. When blow holes are only found

in special castings, or in certain parts of a casting, such as deep points in the drag, or high points in the cope, hard ramming will invariably be found to be the cause, and they are more likely to be found in the cope side than the drag, for the iron when it rises to this point, is comparatively dull and sets quickly, and the effect of the least boiling of the iron is retained in the casting in the form of blow holes.

Another cause of blow holes is the quality or characteristic of a moulding sand that makes it a good moulding sand for one line of casting and a very poor one for another. A very fine grained loam sand is the best sand for light or thin castings, as it gives a smooth surface to the casting. This sand is so close that it does not admit of the gas generated from the sand by the molten iron escaping freely through the sand, but this has no bad effect upon the castings, for light castings generate very little gas, and the iron sets so quickly that the little generated has no effect upon the iron when in a molten state, and it is only an extreme case that there is any blowing of light castings due to this cause. When it does occur it may be prevented by scari-fying the sand under the bottom board and venting freely with a vent wire before rolling over, and also venting the cope freely.

This grade of sand is not at all suitable for heavy casting for the conditions are different. The heavy body of iron generates more gas and remains in a molten state longer than in light castings, and is more susceptible to explosions of gas at the moment of solidification than the iron in light castings. For this line of castings a coarser and more open sand that admits of the escape of gas generated by the molten iron is required.

When blow holes occur with a good sand then the temper of the sand, ramming and venting should be looked after. If blowing only occurs in the castings of one or two moulders, then the cause is in the moulding; if all over the foundry, then it is due to the sand or iron.

Cores are a thing that should be carefully looked after in locating the cause of blow holes. A partially dried core, or one that has been kept in stock until it has drawn dampness is more liable to cause blowing than wet moulding sand, for it is generally almost surrounded by molten iron and the gas is more confined. A fine core sand containing an excess of loam, and also excessive use of some of the core binders may cause the blow holes.

Skimming Iron.

Many castings are lost due to dirt and dross separating from the molten iron, and also from ladle-daubing collecting upon the

surface of the iron in ladles and being carried into the mould with the stream of iron in pouring. This may be prevented to a large extent by thoroughly skimming the iron before pouring. But this does not fully prevent it, for small lumps of dirt and dross rise to the surface of the molten iron as long as it is in a sufficiently fluid state to admit of them rising to the surface. Even when the surface of the iron is closely watched and skimmer is at hand they cannot always be prevented from being carried into the mould with the iron. To prevent this, it is the practice in many foundries to throw a handful of dry parting sand over the iron after skimming; this forms a scum on the iron that catches the dirt as it rises, and holds it from flowing with the stream of iron. The objectionable feature of this plan is that the parting sand adheres to the side of the ladle as the iron is poured and causes dirt to rise more freely in the next ladle of iron.

Another way that is quite extensively used for preventing skimmings entering a mould is to cast a very thin cast iron disk perforated with small holes, place this in the gate or over it, and build up a small basin around the gate and strain the iron through the disk in pouring. This catches the dirt and prevents it entering the mould. Perforated tin plate is also being used in place of the disk with equally good results. There are also an endless number of skim gates in use, all of which are constructed upon the strainer principal. They are generally formed of dry sand cores which are placed in the gates at the parting near the casting. Some of these gates give very satisfactory results.

A side spout on a ladle for drawing the iron from the bottom of a ladle when pouring has been tried many times but always abandoned owing to the trouble in drying and keeping in good pouring condition. Stationary lip skimmer of various designs have been used, but these, too, have generally disappeared after a short trial, and the only practical way of skimming iron in a ladle appears to be to skim the iron thoroughly before pouring begins, and have a man or boy stand ready with a skimmer to remove any skimming that may rise to the surface during pouring.

Casting Iron Around Steel.

It is sometimes very difficult to obtain a sound casting and good weld when casting steel pins, rods or wire in cast iron or alloy metal. This is due to two causes: First, to the steel being cold and having drawn moisture from the moulding sand, repels the first contact of the molten iron with the steel, and if

the body of iron is light, it loses its fluidity before it can return to a proper contact with the steel for a good weld and sound casting. When a good weld is desired of steel in a small casting, the only practical way to obtain it is to place a flow gate upon the casting and flow good hot iron through the mould until a weld is effected. The second cause of blow holes is rust, dirt and moisture upon the steel. The moisture and dirt can be removed by heating, tumbling or polishing, but rust cannot always be removed. For in a badly rusted piece of steel the rust penetrates so deeply into small crevices of the steel which cannot be detected by the naked eye, that it cannot be fully removed even by polishing. And these small rust pits cause the iron to boil and leave small blow holes around the steel in the casting, which in light castings frequently condemns the casting.

To prevent this dip the steel into a mixture of red lead and turpentine, and permit all the turpentine to evaporate before placing steel in the mould. This leaves a coating of red lead upon the steel that prevents the molten iron coming in contact with the rust and prevents blowing. This method has proven very effective in the casting of steel pins, bolts, wire netting, in brake shoes, etc., but should not be employed when a perfect weld of the steel and iron is desired. In such cases only new perfectly clean steel that has not been rusted should be used. No oil is used in the mixture, and the evaporation of the turpentine may be hastened by heat.

In the casting of heavy rolls upon a steel shaft or spindle the steel sometimes becomes distorted to so great a degree that the shaft has to be cut away to a considerable extent before the roll can be made to run true.

This trouble may be overcome by casting the roll hollow. This is done by building up a dry core upon the shaft. For a short roll one core is sufficient. This is made of a length to give an iron bearing of two to three inches upon the shaft. For long rolls, a number of cores are used and placed at a distance apart that gives an iron bearing or column upon the shaft from one to two inches. The vent from the cores is taken off through four small openings in the end. When cast in this way the shaft preserves its alignment and the roll sustains as heavy a load with no greater deflection than when cast solid. There is a considerable saving of iron and lessening of machining which offsets the cost of cores, and for many purposes a better roll is produced.

Notes on Close-Grained Soft Cast Iron.

By John Jermain Porter

At Chicago Convention of American Foundrymen's Association, Professor Porter offered some notes here summarized on the making of easily machined castings capable of high polish and of white surface.

Controlling factor in grain size is no doubt the size of the flakes of graphite, their distribution and number. A desirable iron must have limited graphite, in small flakes and uniformly distributed. Practical means of controlling graphite, grain size and hardness are classified under the following heads: Chemical composition. Use of steel scrap, chips, etc. Selection of kind of iron and brands. Use of alloys. Control of rate of cooling. Cupola practice. Practice in machining.

Silicon should be kept as low as possible without hardening iron too much. Many carry excess silicon to be safe in matter of hardness, and this can usually be cut down.

Sulphur will close grain if excessive, but only at cost of hardness and probably other troubles. Do not consider it safe.

Manganese supposed to have important influence in closing grain, but am doubtful as to efficiency. In moderate amounts it probably has some good effect, but excessive quantity hardens and may open grain, due to formation of large crystals of manganese carbide.

Phosphorus within usual limits, probably has little or no effect on grain size or hardness.

Use of steel scrap is becoming common and is a very excellent means of closing grain and increasing strength. Ten to 25 per cent. is generally used, and if silicon is properly regulated the hardness will not be materially increased.

Addition of chips to the charge also has a strong tendency to close the grain, but in this case again precautions must be taken to avoid oxidation and cupola troubles. Difficult to understand thoroughly the action of steel and chips in closing the grain. In part it is due to decrease in the amount of carbon (and graphite) in casting, but in many cases analyses show close-grained iron to be high in carbon, due to absorption in cupola.

Charcoal iron, if properly used, will give much closer-grained castings than coke iron of equal hardness. There is also considerable difference in behavior of different irons of the same

class, some brands giving better results than others. Apparently difference is due to variations in furnace practice and materials used.

Use of either titanium or vanadium alloy seemed in experiments to give more uniform and possibly a little closer grain structure, but these results would probably have been more pronounced on a poorer grade of iron.

Rapid cooling gives smaller grain size and greater hardness. It is common practice to use chills to form the Vees of lathe beds; size of the chills being so proportioned as to close the grain and yet not actually chill the iron and make it difficult to machine. Cores are also used in some cases purely for their cooling power and to close the grain.

Cast iron may be made close-grained by cooling rapidly through its solidifying temperature and just below, and at the same time soft by cooling slowly through the lower range. Castings can be made considerably softer by allowing them to remain in sand until cold and thus anneal themselves. Since slow cooling through lower range of temperature probably does not affect grain size, a combination of low silicon and prolonged cooling is useful in getting desired properties of softness and close grain.

Bad cupola work is capable of nullifying the effects of almost all the methods suggested for reducing grain size. It may also produce close grain, in combination with hardness, through excessive oxidation. Some think that rate of blowing and blast pressure have a good deal to do with grain structure of iron, and it is true that height of melting zone and coke bed can be an important factor. Higher the melting zone and longer the column of coke through which the iron trickles, the greater the tendency to open grain.

Many machinists, but not all foundrymen, know that a good close-grained iron can appear open-grained. A heavy roughing cut will pull and tear the iron crystals and for short distance below the surface produce a very open structure. If now the finishing cut is very light, or if finish follows directly on roughing cut, iron appears very open-grained, while with proper treatment it may be entirely satisfactory.

Flasks.

There are four kinds of flasks used in foundries. These are the wood flask, cast iron flask and the rolled steel and cast steel flask.

Each of these flasks have their desirable properties and their objectionable features. The wood flask is the one that has been most commonly used in this country, on account of its cheapness and being light and easy to handle. But as the forests disappear and the price of lumber goes higher, this flask is being replaced by other more durable flasks, and will probably soon disappear for any but special lines of castings. The objectionable features of this flask are its tendency to warp and get out of shape when not properly taken care of, to spring when it gets old, and also to burn away very rapidly at the joints and bottom board when used for heavy castings. This can be prevented to a large extent by protecting the joints and bottom of drag with a light cast iron flange fastened on, but this plan, although tried many times, has never come to be a general practice but may become so owing to the advance of flask lumber.

The cast iron flask is the one most commonly used in foreign countries and to some extent in this country. The cope and drag of small flask of this metal are generally cast in one piece, and for special lines of castings the bars are casting in the cope. The thickness of metal is generally from one-half to three-fourths of an inch, which makes them clumsy and heavy to handle. Large ones are cast in sections and bolted together with cast or wooden bars bolted or nailed in through holes provided for this purpose.

A very neat small flask of cast iron may be made by casting it in sections and bolting or riveting it together at the corners. The castings for the sides and ends are made one-eighth of an inch in thickness and ribbed with small light ribs for stiffness and a light half-inch flange at the top and bottom of cope and drag. These flasks after being put together may have pin holes drilled to a gauge and by the use of loose pins be stacked to any height required. These flasks are used in many foundries in the west, and are a very neat flask that is not much, if any, heavier than the rolled steel flask and lasts much longer.

The small cast steel flask is generally cast in one piece and made heavy like the cast iron small flask. It is principally used in steel foundries for dry sand work, and is desired to be strong to prevent breaking in rapping the dried hard sand out of it.

The rolled steel flask is one made from steel rolled for the purpose, with special rolls which give the desired shape and flanging for a flask. This steel when shaped and riveted makes a very neat flask and answers the purpose very well, but is quite

expensive to begin with and the damp sand and foundry gases corrode them very rapidly, so that the life of these flasks is said to be only about three years.

Flask Pins.

There has always been trouble with flask pins on wooden flasks becoming loose and out of place, binding when lifting off and failing to enter the pin plate properly when closing. This is due to the warping and twisting of flasks; lifting one end of the flask and throwing it over when shaking out; careless piling of flasks, etc., and there is also frequently trouble with the pins of iron flasks, also steel flasks, due to carelessness in shaking out and handling of the heavy flasks. These troubles may be overcome by the use of the separate or loose pin and a pin hole plate on both cope and drag.

This pin is made of steel, tempered very hard to prevent wear, with a bent handle on one end and pointed at the other, the body of the pin perfectly straight and smooth and of a diameter to suit the size of flask. These should be of different lengths for long or short lift, and as the pins go common, two or three different lengths are generally provided to be used when drags or copes are stacked for a deep casting in the drag or high one in the cope. The pin plates are cast solid and drilled to fit the pin accurately, and they may be placed on both sides of the drag and cope for stacking for deeper or high castings. When the cope is put on the pins are dropped into the pin hole plates, and when the mould is closed they are taken out and used for the next flask. These pins are very convenient, safe and accurate, and greatly facilitate the shaking out of castings.

Care of Flasks.

The care of flasks is a more important matter than foundrymen seem to realize, and in many cases they are taken out of the foundry into the flask yard and thrown into a promiscuous pile without the least regard as to whether the copes and drags are together or not. Bottom boards are thrown out in the same way, and the result is that both bottom boards and flasks become warped and twisted, the pins do not fit, drags do not lay solid on the board, copes do not lay solid on the drag but rest on two corners, sand has to be put over the drag to get the bottom board solid, and sand has to be placed under the corners of the cope to get it to lay solid. All this requires time and labor, and the casting, if a thin one, is liable to be clamped off and castings lost. If the flask is clamped down into shape before ramming it is liable to spring back after ramming and a drop out may occur.

All this may be prevented by a proper piling of flasks in the yard when not in use. In every flask yard two studdings four by four inches should be laid down perfectly level upon which to pile small flasks and a larger timber for large flasks. These timbers should be laid a distance apart to suit the size flasks to be piled upon them, and perfectly level to prevent warping and twisting of the flask. This will keep the lower flask up off the ground and prevent rotting of wooden flasks and rapid rusting of iron and steel ones by admitting of a free circulation of air under and around them. Each cope and drag should be put together and the bottom board placed upon it. This not only keeps the flasks and boards straight but also keeps them dry and preserves them, as even in wet weather the top board is the only one that gets wet and this soon dries.

Both large and small flasks, when not in use, may be piled in this way and require less yard room, as they may be piled to any height, and flasks last much longer when carefully piled in this way, and many castings that are lost, due to warping and springing of the flask, may be saved. No more labor is required to care for flasks and boards in this way, and a great deal of time and labor is saved in hunting for flasks and putting them in shape for moulding.

Promiscuous bottom boards used for odd jobs and flasks may be set on end upon studding, thus prevent warping and save time in looking for a board of a desired size.

Increased Output of Castings

CHAPTER X

Lost Motion in Moulding.

There is probably no mechanical pursuit in which so great an amount of muscular power and energy is wasted as in moulding. I first noticed this when working at moulding in a foundry in which all the moulders worked piece work, and found that the man working alongside of me was putting up a larger floor of the same line of work than I was and earning more money, although I was a younger and stronger man than he was and working harder. After getting up all the speed I could and failing to keep up with him I started in to study the problem.

The first thing I noticed was that he only peened his drags, cope and bars once, while I peened mine two or three times. He butted the drag only once, and in some cases, only in spots, and one butting was sufficient for the cope, and this was all the peening and butting that was necessary when done in the right place.

I next noticed that he used only one large shovel of sand where I used two or three small ones. All this extra work took time and muscular power, and I was jumping around like a hen on a hot griddle, while he was working apparently slow and easy and accomplishing more than I was. I at once adopted his methods, and after having a few copes fall out, before I learned to peen and ram in the right place, and picking up a few more points from him, I was able to put up a larger floor with a great deal less labor than I had been doing before.

Since then in visiting foundries I have noticed many times moulders making the same mistakes I was making, and while

working hard do not obtain the results they should attain, and would achieve were they using more judgment in doing their work.

It is the practice of many moulders to peen a flask around once, and then go over it again once or twice more, feeling for soft spots with the peen. This is entirely unnecessary for one well directed blow with the peen of a rammer of proper weight, packs the sand as effectively as two or three blows, and the same is the case with the butting, and in duplicate moulding, by a careful study of the necessary ramming, the time of ramming may be reduced one-half in many cases.

The care of a rammer is also an important matter, the peen and butt of a new rammer should be ground and polished before it is put into the sand, for moulding sand adheres freely to a sand coated or rusted rammer, and a blow struck with a peen or butt heavily coated with sand is not nearly so effective as with a clean, free working rammer, and for this reason a rammer should never be permitted to remain in the sand over night and should be cleaned, oiled and hung up.

The care of a shovel is another very important matter in moulding, for when a shovel becomes rusted the loom of moulding sand adheres to it freely, and when heavily coated with sand a great deal more muscular power is required to force it into the sand heap. Only a few seconds is required to clean a shovel with a wooden ledge, which should be done frequently to prevent rusting, and should be carefully cleaned, oiled with a greased rag and hung up after each day's work. The care of shovels in this way makes them work more freely and greatly reduces the expense for shovels as they last much longer.

In many foundries no care at all is taken of moulding shovels. They are left in the sand heap over night, never cleaned, thrown around anywhere, and a new shovel becomes an old one in a very short time. It should be a rule of every foundry, that shovels are to be cleaned frequently, oiled and hung up when not in use.

The care of riddles is also an important matter to the moulder as well as the founder. After each riddling it should be hung up or placed on top of the sand heap, upside down, convenient for the next mould. This permits the riddle to dry after each riddling, keeps it clean and it riddles more freely than if clogged with damp sand, and less muscular power and time is required to riddle sand for the mould. It also retards rusting and makes a riddle last longer. The removal of scrap from the top

of moulds before shaking out keeps the sand heap cleaner and less riddling of sand is required. All other tools should be cared for in like manner, and placed after each using of them, in a convenient place for use again, that no lost motion or time may be lost in reaching or hunting for them. Patterns, follow boards, flasks, bottom boards, etc., should also be conveniently placed and everything reduced to a system that time and labor may be saved.

“Rules to this effect should be placed in every foundry.”

Safety Commandments in Action.

Some rules were posted at a plant for the promotion of efficiency as far as a set of rules and regulations could be expected to go. To make them remembered after they were read, they were put into a form that made a hit because planned on quaint lines, inviting repetition by the readers and occasional good-natured quotation from one workman to another. Here they are:

I. Thou shalt have none other thoughts than thy work.

II. Thou shalt take no unnecessary risks, nor try to show off, nor play practical jokes, for by thy carelessness thou mayest do injuries which will have effect unto the third and fourth generations to follow.

III. Thou shalt not swear or lose thy temper when things do not come just right.

IV. Remember that thou art not the only one on the job and that other lives are just as important as thine own.

V. Honor thy job and thyself, that thy days may be long in employment.

VI. Thou shalt not clean machinery while it is in motion.

VII. Thou shalt not watch thy neighbor's work but attend to thine own.

VIII. Thou shalt not let the sleeves of thy shirt hang loose, nor the flaps of thy coat be unbuttoned, as they may get caught in the machinery.

IX. Thou shalt not throw matches nor greasy waste on the floor, nor scatter oil around the bearings, as a dirty worker is a clumsy worker, and a clumsy worker is a menace to himself and his fellow workers.

X. Thou shalt not interfere with the switches, nor the dynamos, nor the cables, nor the engines, nor anything else that thou art told is dangerous.

Elimination of Waste Motion in Bench Moulding.

Planning the practice and then improving it, studying men and equipment, supplying the workman with sufficient tools, neatness in the foundry, and some remarkable records show use of studious oversight.

Complete planning out in advance by the foreman of work is becoming more of a necessity. Cheaper and quicker methods of operation must meet the changing conditions tending to closer competition. All orders received have to be analyzed carefully for cheap methods of production, special apparatus and machines being one of the important features of cheap output. The best foremen and superintendents are always viewing the work with a critical eye, constantly asking themselves if it cannot be done in a better way. They do not allow themselves to be hampered by the traditional ways of the past.

We will show by an example how similar methods of investigation may be used in working out everyday questions of improvement in the foundry. To best explain the method we may study the ordinary molding bench and the operation of turning out any simple casting in small quantities.

Waste motion and inefficient methods are common occurrences in moulding, so careful study of the operations performed was determined upon. To get the best results, a detailed time and motion study was made of operations in bench moulding. This itemizing may seem useless to many, but it is well known that important facts are missed by not obtaining for analysis the seemingly unimportant small detail.

Time studies were made of men under ordinary shop conditions. The results of these studies are shown in the table of the record of time study in column A.

Analyzing the work done under these conditions, three facts were impressed upon the minds of the investigators:

One cause for delay was due to not having tools in most convenient positions for handling. They were often covered up with unnecessary odds and ends, like unused patterns, extra gate-pins, old cores, etc.

Very often the workmen did not have the necessary tools and quite often those he did have were not in very good shape.

Blunt draw-spikes, inefficient rapping hammers, swabs, sand cans, etc., were in evidence when he was left to supply his own tools and keep them in shape.

Moulders do too much unnecessary work, such as taking several small shovelfuls of sand to fill a cope or drag when one or two heaping shovels would produce same results.

It was found best to have benches made of the wall type, although in majority of cases the portable bench was constructed with the idea of less handling of sand and moulds. The moulding bench was constructed with the idea of having a place for every necessary tool and all supplies, having each within the most convenient reaching distance. Arrangement is such that tools cannot be anywhere but in the proper place; and the foreman or moulder can see at a glance whether they are in good condition.

With a place for everything actually needed and only those tools and supplies around, the common fault of the workmen of having benches littered up with extra tools, patterns, old cores, gate-pins, etc., was done away with.

Small tools, slick, trowel, gate-cutter, etc., are kept in the tool tray. The box sets on its stand and is tilted at an angle so moulder can see each tool and get the one needed with practically no loss of time as in searching for it on his bench. Box is returned to the toolroom each evening where attendant sees that tools are in good shape. If special tools are needed, they are placed in the box issued to the moulder assigned to that order.

Under toolbox is a shelf for a core tote-board. Rammers and strike-off are kept directly in front, easy of access and when replaced they can be thrown into holders with one motion of arms.

Wire basket holder for sprue and riser pins is at back of bench. This is a convenient position, the wire preventing accumulation of sand as in a tight box or shelf.

Two brackets are for setting the cope onto when there are no patterns to be drawn from it. When patterns have to be removed from cope it is rolled over onto side. Dust-bag and swab-can holders are at right of workman for ease of access.

Riddle is in rack at right side of bench. Above the sand, it is never in the way as in ordinary practice. Sand is shoveled into it easily and it can be picked up with less trouble than having to reach down to floor level.

Authors a year ago, in what is supposed to be one of the largest and best shops in the country, noticed that one spirit level was common property among fifteen loam moulders and an enormous amount of time was lost by them in looking for it.

In bench work the shovels must not be worn too small or used with edges turned. Much effort is wasted with dirty shovels. Toolroom attendant sees that edges are in good condition and keeps blades oiled when shovels are not in use.

Draw-spikes are inspected for sharpness, and proper sized gate-cutters, swabs and draw-screws are issued. Bell-top sprue-pins are used wherever possible because they save time of striking off and reaming out. Special wide strike-off iron, one stroke finishing the operation was adopted. Straight steel bottom-boards are used for durability and the strike-off leaves smooth surface on drag and no time is lost bedding board on a soft layer of sand.

One heaping shovelful of sand in riddle was usually found all that was necessary for drag or cope. Many small shovelfuls of sand to fill cope and drag for peening and butt-ramming was replaced by two and three large shovelfuls. Careful placing of bottom-boards for ease in reaching was observed.

Instruction cards are made for the men working with different patterns as orders come in. These contain information as to flasks, special tools, special gating, how cores are to be set and anchored, and other details generally left to discretion of moulder. Cards are issued to moulder with tools and work order. Made up by the most experienced men, they insure quickest and best methods of gating, holding of cores, etc. A special place is on bench for holding these cards where easily read. Value of written instruction is that best method of making the piece is planned out ahead of doing the work. These cards relieve the foreman of repeating verbal instructions and avoid misunderstanding. The use and writing of instruction cards impressed on the management the need for standardization in tools, materials, and methods of work.

Table gives conditions before the work of investigation was started and the outcome of following the suggested improvements.

Column A gives averages obtained in ordinary practice. Column B gives average time of making molds similar to those of column A, but which were made on the well arranged bench while instructions as to striking off, filling, riddle, shoveling and ramming were followed. Items 19 and 21 produced largest dif-

Successive Operations in Making Mould		A Average of studies Minutes	B Average of studies Minutes	C Average of eliminated time Minutes
1	Placing flask on bench. Setting patterns	0.18	0.18	0.00
2	Placing riddle; fill, cover patterns	0.16	0.13	0.03
3	Tuck around patterns.....	0.07	0.07	0.00
4	Fill drag	0.15	0.11	0.04
5	Peen-ram	0.11	0.09	0.02
6	Butt-ram	0.07	0.06	0.01
7	Strike-off	0.16	0.06	0.10
8	Place board on drag. Bed board	0.09	0.05	0.04
9	Roll drag over; remove board	0.09	0.09	0.00
10	Set patterns	0.23	0.17	0.06
11	Set gate; cover with riddled sand	0.33	0.22	0.11
12	Truck around patterns	0.11	0.11	0.00
13	Fill cope	0.23	0.17	0.07
14	Peen-ram	0.18	0.12	0.06
15	Butt-ram	0.06	0.06	0.00
16	Strike-off	0.16	0.06	0.10
17	Remove sprue-pin	0.07	0.07	0.00
18	Lift cope; roll cope.....	0.30	0.30	0.00
19	Clean gate; remove patterns cope; repair cope.....	0.80	0.30	0.50
20	Rap and draw patterns from drag	0.47	0.40	0.07
21	Vent for cores; patch.....	0.40	0.20	0.20
22	Set Cores	0.17	0.15	0.02
23	Dust drag and cope.....	0.12	0.10	0.02
24	Close cope	0.31	0.25	0.06
25	Remove flask	0.15	0.15	0.00
26	Set flask on floor.....	0.16	0.16	0.00
		5.34	3.83	1.51

Comparative Record of a Time Study in the Foundry.

ference because molders will use patterns that tear mold slightly in drawing. Time of patching seems so small that they do not think it necessary to have pattern repaired. Savings in time of items 2, 5, 7, 8, 10, 11, 14 and 15 due to changing of benches which facilitated the handling of tools and supplies and the use of wide strike-off, bell-top sprue-pins, steel bottom-boards, etc. Other minor time differences due to good tools, proper handling of shovels, riddle, rammers, etc.

These small savings when totaled up for each man for a year's work amount to an astonishingly large amount. One minute less a mold, if molder puts up eighty molds daily, means that each day an hour and twenty minutes will be gained for productive labor per man.

This study, further suggest R. E. Kennedy and J. C. Pendleton, of Urbana, Ill., authors of above paper at Chicago convention of American Foundrymen's Association, is only one of the many possible in every foundry; floor molding, corerom work, cupola tending, and all other branches of foundry practice can be analyzed to reduce time and costs.

Foundries In a Rut.

Foundries are said to get into a rut. This is a very old expression, commonly applied by teamsters to a bad place in a road, into which their wagon gets stuck, and their team is unable to pull it out. This term as applied to a foundry, means that the foundry is unable to produce satisfactory castings, and the management is unable to locate the trouble and pull it out of the rut into which it has fallen.

This condition is more commonly found in large foundries than in smaller ones, and is generally, or I might say, always due to incompetent men in some departments, or neglect to do something that they should have done, or were not permitted to do, by an incompetent manager. To illustrate this, I will cite the following cases:—

I was called to investigate rut trouble at a large foundry and learned that they were casting a line of heavy and light machined castings for their own consumption. A large per cent of the castings, both large and small, were being scrapped, and many of those accepted were not up to a desired standard for their high grade machinery.

In looking over their castings, patterns, flasks, moulding sands, mouldings, melting, etc., for a few days, I found that many

of their castings were lost due to crushing and patching the moulds, fall outs, hard ramming, etc.

Many of the patterns were old and knocked to pieces by rapping, and patching of the mould was necessary. Many of the flasks were too light for the heavy castings moulded in them, and swelling of castings due to this cause occurred. Their iron was being poorly melted, coming down hot in one part of the heat and dull in another, etc. These were matters that could not be changed in a few days by an expert, and I reported what I had learned to the management, and suggested that they employ a foreman who was familiar with the requirements for their line of castings, and capable of putting their plant in shape to turn out good castings.

This advice was followed, and the man advertised for. One applied who after looking things over a little, stated he could get things in good shape in a short time, and be turning out good castings in a month. Two months went by and no improvement, and he was let go.

Another man applied, who stated he could make the necessary changes in their plant in three months and give them good castings. At the end of three months, castings were coming worse than ever and his services were dispensed with.

The next applicant was employed for a week, to look over the plant and report what changes were necessary, how long it would take to make them, etc. He reported the necessary changes, and stated the plant could be gotten in fairly good shape in a year. But a longer time than that would be required to get everything perfect.

He was put to work and things at once began to improve. At the end of his year, he being of a roving disposition, was ready to go, but his work had been so satisfactory that the foundry was out of the rut and the firm was so well pleased with results, that they raised his salary, and induced him to stay another year, and they have induced him to stay from year to year, increasing his salary from time to time, until now he has been in their employ for twenty-five years, and is the highest salaried foundry foreman in the country at the present time. Their new foundry, designed by him, is one of the largest and best equipped foundries for heavy and light machined castings in this country.

This was a management that understood its business, and went at things in the right way. They first learned what their trouble was, and then went after a man competent to get them

out of it, and when they found the man, were willing to pay him what his services were worth to them and made a success of their business, which no doubt would have proven a failure had they continued to run their foundry in the rut into which it had fallen.

At another foundry which was a large stove and heater plant, to which I was called, I found them losing as high as sixty per cent of their steam boiler castings, and also a large per cent of other heater castings. This heavy loss had been going on for some time, and the stove department had been made to pay the running expenses of the heater department.

The company had changed foremen a number of times, moulders had been changed, various grades of sand had been tried, and everything that was suggested tried, but the heavy loss of castings still continued and it looked to them like a complete hoodoo.

After learning the various remedies they had applied to reduce their heavy loss, I looked over their patterns, follow boards, flasks, and castings, and found the patterns in bad condition, and in need of waxing; follow boards worn and warped, to an extent that the patterns did not lie solid upon them, and they did not leave a good parting; and many of the flasks were old and shaky. An inspection of the scrap casting showed that many of them had been lost, due to fall outs, crushing of the mould, an extra thickness of castings, due to patching up of moulds, blow holes, scabbing, etc.

I next watched the moulders at their work, and found that patterns did not lie solid in the sand of the drag when rolled over, and were being rapped down, and sand peened or tucked around them to get them solid. In this they did not always succeed, and bad lifts were common and copes had to be returned to the drag, from one to three times and rammed over the sand that did not lift, before a clean lift could be effected. Sand was being worked too wet to secure a good lift, moulders were vexed and excited over their failure to turn out good castings, and were resorting to all kinds of absurd things in moulding, to get better results.

The heavy loss of castings to my mind was clearly due to bad moulding, and the bad moulding was due to a poor rig for the work to be cast.

I reported this to the management and suggested that the patterns be put in good conditions. A new set of follow boards be provided and the old worn-out and shaky flasks be replaced

with new ones, and longer pins be placed upon some of them to insure straight lifting.

These suggestions were followed out and in a very short time the heavy loss of sixty per cent was reduced to the normal loss of about five per cent.

Another foundry that I investigated, making a special line of medium heavy castings for their own finishing, to be machined all over, and required to be perfectly clean and as high as sixty per cent of these castings were being scrapped, after partial or about complete machining, before their defects were found, and forty per cent was considered a normal loss.

This was a large plant, employing about fifty moulders, only a small per cent of whom were moulding the castings referred to. The others were employed in moulding plains, toys, and other very light castings.

I was informed that they only had two cars of coke, one of which was good coke and the other very poor coke. This coke had to be mixed in melting, for coke was scarce, and they could get no other. The same mixture of iron was being poured into the heavy castings as into the very light castings, and there was no iron in stock or steel scrap at hand from which a suitable mixture for these castings could be made.

I remained at this plant for three heats, the first of which run short about five hundred pounds of iron. A second heat a ton of over iron to pig out, and the third run short.

A sufficient weight of steel scrap had been collected for a special mixture, but this the manager would not permit to be melted on the bed, for the light castings had to be poured first, and with the foreman's method of figuring up his heat, it could not be melted at the end of the heat, for there was no certainty as to the end of a heat, and it was just as liable to be poured into the light castings for which it was too hard, or into the pig bed, as into the castings for which it was melted.

After three days spent at this plant, and having accomplished nothing, I gave it up as a bad job, and later on learned that two other foundry experts, who had been there before me, had failed to effect any improvement and given it up as I had done.

A few months after my visit to this plant, a first class up-to-date foundry foreman, who I could recommend, wrote me that he desired to make a change, and he inquired if I knew of any vacancies. I wrote this firm in reference to him, and received a reply which was, in part, as follows:

"While we agree that it is quite possible for one to get into a foundry rut, we do not believe that that could be the cause of the trouble which we have had, which, however, has been pretty nearly eliminated as we have not adhered to any particular old methods. On the contrary, we have been continually trying out various methods and devices for ten years. At the present time we would not be interested in the suggestion that you have a man whom you could recommend."

Ten years, it appears to me, was quite a long time in which to learn to produce castings free from dirt, and that they had not succeeded in doing so with two years more added to this length of time, was apparent from a car load of these castings that I was shown last year by a foundryman who had purchased them from this firm as scrap.

The heavy loss in moulding, core making, cleaning, pickling, and machining these castings before these defects were found was sufficient to bankrupt most any foundry company in ten years. But in this case, the loss was made up from profits on other lines of castings and the plant kept running. To make one line of castings pay for the loss of another line of castings is the poorest kind of foundry practice.

The heavy loss of these castings was clearly a case of mismanagement on the part of the management, in retaining in their employ for years a superintendent who could not produce satisfactory castings, or suggest a method to reduce their heavy loss to the foundry and also to the machine shop.

The foundry foreman, who had been employed for years, had resigned about a year before my visit to the plant, and his assistant, a moulder who had been taken from the floor and made assistant foreman, was put in his place.

To promote an assistant foreman familiar with the patterns and conditions is good policy, when things are going along smoothly, but to promote an assistant foreman when such a large per cent of castings had been lost every heat, for years, was the greatest mistake a superintendent could have made for saving the castings. For the assistant knew nothing more than the old foreman had taught him, and was bound to do the same things the foreman had been doing and meet with the same success and failures he had done. A foreman of broad experience, who could devise ways and means of saving these castings and also introduce new and improved methods of doing things into the foundry should have been employed.

These castings, which were lathe chucks, large and small, were out of place in this foundry, for they required an entirely different grade or mixture of iron than that for the light bench work castings. This iron should have been melted upon the bed, and kept separate from the very soft iron by an extra heavy charge of coke to retard the melting to an extent that prevented the close and soft iron mixing, or a small cupola should have been put in to melt the chuck iron. If the weight of iron to be melted was not sufficient to justify either of these methods, then the pattern should have been sent to another foundry, for it would have been more profitable to buy these castings than to make them with the heavy loss on castings and in machining.

The mixture for these castings should have been about as follows: Silicon 1.75—2.00, Phosphorus 0.30, Manganese 0.40, Sulphur under 0.08. This would have given a close but free machining casting.

A stronger but equally free machining metal with a better finished polish would have been about Silicon 2.00, Phosphorus 0.30, Manganese 0.30, Sulphur under 0.08, steel scrap 10—20 per cent. In case the metal was too hard for machining, increase the Silicon or decrease the steel.

At another foundry the castings complained of were semi-steel projectiles. A large number of these had been cast before the machinery for finishing had been put in, and when machining was begun it was found that from ninety to ninety-five per cent of them were so dirty that they were condemned by the inspector, and the loss for castings and machining had been so heavy, the company had been forced into the hands of a receiver.

The mixture for these castings had been made under a fake semi-steel, high manganese formula, which called for two or three per cent manganese in the casting.

This per cent of manganese, when melted with a Southern high silicon pig and steel scrap, caused the silicon to separate from the iron in the shape of dirt and dross, and in some cases, as a pure white silica sand which was found in patches of considerable size in many castings.

A change in the mixture to silicon 1.50—1.75, manganese 0.40—0.50, phosphorus 0.20—0.30, steel scrap 25—30 per cent, gave a perfectly clean casting.

A foundry making gas and oil stoves and ranges had trouble with their burners, and called me in to see if I could locate their

trouble. Their burners were drilled with a set of very small drills, run at a high speed, that drilled all the holes at one time, and when a hard casting was struck by the drills, they were liable to all be destroyed the instant they struck the hard iron.

The softest iron was melted for these castings, and they generally drilled freely, but every few days they would find a few hard ones that destroyed the drills before they knew they were hard.

The hardness was not due to the mixture of iron being hard, for in that case they would all have been hard, and the hardness must be due to some local or special cause, which they had been unable to locate.

I first inspected their pig, scrap and remelt, next watched their charging and melting, and found everything as perfect for the production of a soft iron as could be. I next watched their moulding and pouring, and found that no excessive swabbing was being done, and there was no apparent cause for hardness in the temper of the sand or moulding. I then gave my attention to the pouring, the first thing I noticed was that in warming the hand ladles for light castings, with the first tap of the cupola, the iron boiled badly in all the newly lined ladles, and threw off a heavy smoke with a strong sulphurous odor, these ladles when filled for pouring, after being warmed, boiled slightly, and threw off a slight sulphurous odor. I followed one of these ladles with a new daubing to the floor, and arranged to have the castings from this and each subsequent ladle of iron poured from this ladle kept separate.

The following day, these castings were tested under the drill, and the castings from the first ladle found to be too hard for drilling. Those from the second ladle, close but could be drilled, and the remainder of the castings soft and free drillers. The next day a similar test was made, with the same ladle and scull, and all the castings found to be soft. These tests convinced everybody interested that the hardness was due to a fresh lined ladle, not properly dried.

The next thing to be done was to determine why this ladle was not thoroughly dried after baking and being filled with molten iron, and where the sulphur that had rendered the iron too hard for these light castings had come from.

The next thing in order was to inspect the ladle lining material, this I found to be a clay obtained from the bottom of a coal mine, and heavily impregnated with sulphur and practically

a fire clay, from which the water in combination could not be driven off by the heat of a ladle drying oven.

A loomed sand ladle lining material and a thorough drying of the ladles, was all that was necessary to stop the hardness in these castings.

New moulding sand generally makes the very best daubing for hand ladles ; this material dries quickly and may be so thoroughly dried by the heat of a ladle oven that no boiling of the iron occurs in a newly lined ladle. In case the lining cracks in drying, add a little sharp sand to the moulding sand.

Making a Foundry Plant Pay

CHAPTER XI.

Location.

In establishing a foundry plant, the first thing to be considered and decided upon, is a plot of ground at a suitable location. This plot should be on high or dry ground, so that the moulding floors are not so wet, in either dry or wet weather, as to admit of the moulding sand drawing dampness from the floor and becoming too wet for moulding; also admit of holes being dug in the floor for bedding in work; or pits sunk for heavy work.

The plot should be of a size and shape that will admit of all necessary buildings, sheds and yards being placed in the most convenient and economical positions. This is a matter that is frequently overlooked in starting a foundry plant. There are many foundries, especially in the large cities, with flask yard a long distance from the foundry, and the carpenter shop an equal distance in another direction. Pig iron, scrap iron and coke stored in the cellar, all requires extra labor, which greatly reduces the profit of the foundry.

The location of a foundry plant is a very important matter, for a foundry may be a complete failure, even when it has abundant work and unlimited capital, due to its unfavorable location. A foundry, whether large or small, should be located on a railroad where a siding can be put in. All the raw material used in a foundry are heavy and the hauling of pig iron, scrap iron, coal, coke, sand, etc., is expensive and most, if not all of these materials, have to come by rail from a distance, and the expensive hauling of raw materials, and the finished castings greatly reduces the profits of a foundry.

A still more important matter to be considered in locating a foundry is the labor problem. Moulders, as a rule, are a lively bunch, that like to go out in the evening, and more especially after pay day, for a jolly time, and if the location of a foundry does not admit of this, they cannot be induced to stay and after the first or second pay day, give up their job and look for one in a more congenial locality. This was found to be the case by the Baldwin Locomotive Works, only a few years ago.

The works of this firm had outgrown their foundry capacity in Philadelphia, Pa., where there was no room for foundry enlargement in connection with their works, and they decided to locate their foundry in connection with their steel axle plant, at Burnham, Pa. Burnham is a small manufacturing town or village three miles from the railroad and connected by trolley with Lewistown, a small, quiet rural town on the main line of the Pennsylvania Railroad, forty-one miles west of Harrisburg, and about an equal distance between Philadelphia, Pittsburgh, and Baltimore, all large foundry centers.

Three foundries were built at this place, each one hundred feet wide by three hundred feet long, and fully equipped for foundry work. Advertisements were placed in the Philadelphia, Baltimore and Pittsburgh papers, for moulders to man them. All the moulders employed in their Philadelphia foundry were sent to this plant, and many obtained by advertising had their carfare and expenses paid to Burnham. But they all returned after one or two pay days, and the firm was never able to operate more than one of these foundries and soon found it impossible to keep this one filled with moulders. The entire plant had to be abandoned and three other buildings were erected at Eddystone, to which the equipment was removed. Eddystone was a very small town even smaller than Burnham, but was only a few miles from Philadelphia, and connected with the city by a railroad, and two trolley lines, and after arranging for work trains on the railroad they had no trouble in keeping these three foundries well filled with moulders. In this case there was no scarcity of work, or a lack of capital, and the failure of the plant was wholly due to the fact that moulders could not be induced to work in such an out of the way place:--

There are many foundries today scattered all over the country, that like this one, are a failure for the reason that they are so located that they cannot keep moulders, and are dependent upon tramp moulders who seldom remain more than one pay day, and when work is plenty there are no moulders to be had,

Even when moulders are induced to move their families, and locate at these foundries, they frequently have to be kept at work at a loss, when work is scarce, to prevent them getting employment elsewhere and moving their families away.

A stove foundry located at Columbia, Pa., overcame this difficulty by employing a liberal number of apprentices and making their own moulders. Their plan was to only employ boys of good families, and graduates of the high school of the town. These boys were taken on a month's trial and if satisfactory at the end of that time, were made regular apprentices, who soon developed into good moulders. By promptly discharging any moulders who acquired the drinking habit, after warning them three times to stop it, they have at the present time as good a class of moulders as can be found in any foundry in the state, most of whom own their own homes, and are interested in the welfare of the town and foundry, and by their example and success have made the stove foundry the most desirable place of employment in the town. The firm have no trouble in getting all the high school graduates they require to keep up their supply of moulders.

Another mistake frequently made is in locating a foundry in a town where there are no foundries, but a number of manufacturing plants using castings, with a view of getting all the castings of these plants to make. The buyers of castings, like other buyers of goods, frequently prefer to place their orders for castings where there is competition, and their large orders generally go to the foundry centers and the home foundry only gets the breakdown or hurry up castings to make. Jobbing foundries so located are seldom a success unless there is a large surrounding territory to supply or nearby towns from which orders can be secured. Such foundries should keep a good supply of pig iron, and a small pile of scrap iron in sight, for if the foundry once gets the reputation of using all scrap, their home trade is done for.

All small jobbing foundries should have a specialty of some kind to make, this enables them to keep their moulders at work when jobbing work is scarce, and put them all on jobbing work when there is a rush of orders.

Designing a Foundry Plant.

In designing a foundry plant, the labor problem must be fully considered for the only producers in a foundry are the

moulders. If these are loaded down with overhead labor expense, the foundry cannot possibly be a paying proposition.

To be included in overhead labor of a foundry plant, is the manager and office force, superintendent, foreman, draftsman, pattern makers, engineer, fireman, flask makers, coremakers, moulders' helpers, cupola man, teamsters, and every man that receives his salary or day's pay from the foundry except the moulder, are non-producers, to the extent that their time is charged to the foundry, and are dependent upon the profits made on the output of castings. It will, therefore, readily be seen that the designing of a foundry plant, to reduce the amount of labor required, is a very important matter.

The plot of ground should be of a size and shape to admit of all necessary buildings, sheds, and yards being properly placed, and also for enlargement of the plant, as the business increases. The cupola should be placed at the nearest point to the pig iron and coke, that no extra labor may be required in the handling of the cupola stock. The tumbling barrels for the dump should be placed in the cupola room, and not in the casting cleaning rooms, where the labor of wheeling the dump to the barrel, and wheeling the iron back to the cupola may cost more than the value of the iron recovered.

The moulding room should be arranged to give the shortest possible care for the molten iron from the cupola to the mould. The casting cleaning room should be placed at the nearest point to the final destination of the casting in the plant, that there may be no carrying of them backwards and forwards.

The flask yard should be located right at the foundry door, and the carpenter shop in the yard, to save a long carry of flasks out and in the foundry, and also for barring and repairing.

Many foundries do not employ a regular carpenter, but have a handy man, trained to do the flask hunting, carrying, barring, and repairing, and when there is none of this work to do, employ him at other work.

The pattern shop and pattern storage house should be fire-proof, and near the foundry.

The coke and sand sheds should be placed along the railroad siding, that coke and sand may be shoveled directly into them

without extra handling, and the pig and scrap yard should also be placed on the siding at the nearest point to the cupola.

Foundry Yard.

The foundry yard should be an orderly place, because order makes for safety. Therefore every argument in favor of order is an argument in favor of the safety of employes, and every activity toward orderly conditions is a move in the direction of safety. The orderly yard, because it is more commodious and accessible than the disorderly one, offers greater inducement to move back and forth, as needed, those parts of the foundry equipment which would otherwise litter and crowd the foundry buildings. When, therefore, the entire area of the yard is made conveniently available for the storage of materials and equipment, the yard greatly relieves the otherwise congested condition of the foundry interior, adds to the latter's productive capacity and makes it easier to preserve safe and orderly working conditions in it. This is especially recognized in foundries where every square foot of floor area is valuable for production and where order and light are essential to the greatest safety of the men.

A Moulder Owning a Foundry.

A great many moulders have an idea that they know all about moulding and the foundry business, and all they have to do is to build a foundry and run it to make their fortune. This was my idea in my younger days and I tried it out to my sorrow.

I had served my apprenticeship as a stove plate moulder in a large stove foundry in Pittsburgh, Pa. From this plant I went to work at a small foundry at Sharon, Pa., with one set of stove patterns, one jobbing moulder and a melter, casting every other day. The melter ran the cupola one day and cleaned castings the next day. The three of us were the entire foundry force. After working in this foundry for several years, I secured employment in a large jobbing foundry where I was soon able to mould anything that came in, and rose to the position of foreman, which I held for several years. During the time I had spent in these various foundries, I had learned to manage a cupola and melt iron as well as a professional melter, mount a stove, make or bar a flask, make dry sand cores, and in fact do anything about a foundry. I had saved considerable money and concluded to have a foundry of my own, fashioned after the one that made stove and jobbing shop work, which had

proven a success. This foundry I located at Coshocton, Ohio, where I purchased a lot, put up a building, installed an engine, blower, etc., purchased a set of stove patterns, had flasks made for them and was ready for business. By this time my money was about all gone, but I managed to get a car of iron and one of coke, make a start and worry along for a short time. I then took in a partner who agreed to furnish working capital, equal to the amount I had invested in the plant. This he failed to do, and after two years' endeavor to make the venture a success, I sold out my interest, losing about all I had invested.

This has been about the experience of a number of moulders I have met, who started foundries, and who, like myself, did not know working capital was necessary, or failed to provide it, and there are a large number of such foundries in existence today, built by moulders, the owners of which would be better off if they were working in the foundry for a day's pay.

A moulder who contemplates building or owning a foundry, should first get an estimate on cost of everything required for the line of castings he proposes to make, whether a specialty or general line, and figure out total cost for foundry and equipment. To this cost he should add from ten to twenty-five per cent, for there is always something that has been forgotten or costs more than he estimated. To this estimate he should add an equal amount for working capital. With this amount of working capital he can only do a small hand-to-mouth business. If he designs to push the business to the full capacity of the plant, whether large or small, he should have a working capital equal to at least four times the cost of the plant and outfit, for iron, coke and a complete line of foundry supplies, must be carried in stock. New flasks, patterns, etc., must be provided frequently and money must be on hand to pay workmen on pay day. Castings cannot always be sold for cash, and many accounts have to be carried on the books for months, and some of them forever.

A working capital of four times the cost of plant, will no doubt seem very large to many moulders who contemplate owning a foundry, but a little investigation will show them that many of the sash-weight foundries, which are well known to have the cheapest kind of an equipment, for so few patterns and flasks are required, have several times this amount of working capital, for although their expense for patterns and flasks is very limited, they have to take advantage of the iron market; to compete with other sashweight foundries; and frequently buy large lots of condemned pig or scrap to get it at a low price,

and they have to carry their weights until they get an order for them. One of these foundries, employing only six moulders, the management of which I am well acquainted with, have a working capital of \$50,000, while their plant, when stripped of its weights and irons, would not sell for more than five thousand.

A moulder, who has mastered the foundry end of the business and desires to own a foundry, had better rent a foundry and learn something about the financial end of the business before attempting to build or buy one.

Machine Shop and Foundry.

Many owners of machine shops, using quite a number of castings which at times they find too hard for machining, and at other times cannot get the castings just when wanted, have constructed small foundry plants in connection with their machine shop, to make their own castings. Another inducement in constructing such a foundry is to save the profits made on castings by the foundry. This is a mistake, for castings made in these foundries generally cost more than for what they can be purchased, and in many of them, cost more than double what they can be bought for from another foundry, and the castings are not any more satisfactory. This is due to various causes.

These foundries are generally constructed for the employment of from two to four moulders and are frequently poorly designed. The cupola being poorly placed, and at a point that gives a long carry for the fuel, iron and removal of cupola dump. The cleaning room is placed at a point to which the castings have to be carried some distance, and then back to the machine shop, in place of having it adjoin the machine shop and connected with it. These arrangements require labor out of proportion to the number of moulders employed. Then again, the flask yard is some distance from the foundry and carpenter shop on second or third floor of the machine shop. Moulders in these small foundries are generally required to hunt their own flasks, take them to the carpenter shop when necessary, and frequently have to do the work of barring or repairing them. This takes up the valuable time of the moulder, and results in the small output of castings for his day's pay. Another cause for high cost of castings in these foundries is scarcity of work at times and the moulder killing time to make the job hold out, and establishing a small day's work for the plant and even when there is a rush of work on do not do a full day's work.

One of the best ways to make a foundry of this kind pay is to have a specialty on which one or more moulders can be con-

stantly employed working piece work, and one or more moulders working by the day, making orders or stock castings, with patterns always at hand, for stock castings when ordered castings are scarce, and in this way, give the moulder no excuse for killing time on a mould and insure a fair day's work.

With this system and casting every second day, a man to do the melting one day and cleaning castings the next, is all that is required for two moulders. A melter and one laborer, part of his time, is all that is required for four moulders casting every day, or every other day. This brings the labor down to a proper proportion to the moulders, and with moulders that are willing to do a fair day's work, any of these foundries can make castings as cheaply as any of the larger foundries, with heavy overhead charges.

Foundry Foreman.

The foreman of a foundry is a manager and not a workman. If he has only two or three moulders he may find time to do a little moulding, but if he has eight or ten moulders, working on jobbing work, or other castings in which changes are frequently made, all his time can be more profitably employed in giving out the patterns to men competent to mould the piece; seeing that the flask is at hand in good condition and properly barred; seeing that patterns are properly gated, rammed and poured; cores are properly made, vented and baked; patterns are in proper condition for moulding, and that they are not rapped and battered to pieces, by careless moulders, before a half dozen castings are made from them. Seeing that each moulder does a fair day's work for his wages. If castings are bad, to determine the cause and see that the next one is not lost from the same cause.

He should see that the cupola is properly chipped out, daubed and lining in shape to do fast melting, and everything done to give fast melting and hot, even iron throughout a heat. When he has properly looked after all these things, he has no time for moulding. It may be claimed that the melter and moulders are competent men and do not require this attention and looking after. This may be the case, but men grow careless and there is nothing like keeping them up to the standard by letting them know that the foreman understands his business and is noticing what they are doing and how they are doing it.

This should not be done by continual nagging and finding fault, but should be done by calling the man's attention to things that are not right, and advising him what to do to make things

right. If he pays no attention to such advice and goes on in the same old way, with bad results, call his attention to it again, and if he does not improve, do not quarrel with him, but lay him off on pay night, with a polite note that his services are no longer required, for every man has his friends that are ready to side with him, no matter how much he may be at fault, and quarreling with a man about his work may result in an ill feeling throughout the shop toward a foreman.

In these days of close competition, the success or failure of a foundry plant depends, to a very large extent, upon the foundry superintendent or foreman, for upon him rests the responsibility of getting out the castings of a desired quality at the least possible cost for materials, supplies and labor. To do this there must be a complete planning out of the work in advance of doing it. All orders received have to be analyzed carefully, for a cheap method of production. He must not allow himself to be hampered by the traditional ways of the past and consider those methods the only way in which the work can be done.

When an order for castings is received the first thing he does is to learn the number of castings to be made from each pattern. He then looks the patterns over to see what cores are required; how many patterns can be placed in a flask; how they are to be gated, etc., and sees that the pattern is in good condition for moulding before giving it to the moulder, that there may be no time lost in patching up the mould.

In case there is only a very limited number of pieces to be cast from each pattern, the question of flasks must be considered. Is there a flask in the foundry or yard in which the piece may be moulded and cast? If not, can it be bedded in the floor and coped or can any flask in stock be changed at a small cost and made to answer the purpose and the cost of a new flask saved?

If there are a large number of pieces to be cast from the same pattern, then the question is what kind of a rig can be devised to turn them out quickly, and the least possible cost for rig and moulding must be considered. First, the number of patterns that can be moulded in a flask; size of flask that may be used to best advantage; set gates to break off clean and reduce weight of iron in remelt, bench, floor, or machine moulding, etc. The rig problem is one of the most important to be considered, and one to which more attention is being given at the present time than any other. For it has been found in many cases that from two to four times the number of duplicate castings can be turned out with the proper rig than were formerly turned out in the same

time and in many cases with less labor and cost than was required by old methods.

Foreman a Failure.

Foundry foremen are frequently a complete failure. Some from being overzealous in their work; others from lack of ambition and interest in their work; others from lack of judgment in laying out work; in selecting a moulder competent to mould the piece; handling the men to the best advantage, etc. Others are a failure due to their uncontrollable desire to do more muscular work than brain work, and permit the men to do as they please, regardless of results.

One of the most successful foremen that I know of, for large castings and heavy work, was employed at a large foundry in Milwaukee, Wis. He very seldom lost a casting of any importance and his castings were as perfect as the casting could be made. He always saw that the pattern was in good condition; that the flask was of the proper size, correctly barred and nailed; he selected his best moulder to make the moulds and the result was a perfect casting.

This man had no faculty whatever for making things do. He could not take a flask that was not the exact size or shape and have it raised, shaped and barred to mould one or two castings, but must have a flask and rig exactly suited for the casting, and never started to mould until everything was perfect. He then put his best moulder to work on the job and turned out a perfect casting.

This foreman was a high-salaried man. He paid his best moulders the highest wages he could get for them. His requirements in patterns, flasks and rig was very expensive, and the result was that many of his castings cost more to make than his employer was able to get for them, and he was let go, not because he was not a competent man, but for the reason that he was too expensive a man. From this plant he went to a large engineering plant in Eastern Pennsylvania, where he was only employed for a short time and let go for the same reason, too expensive a man.

This man was an excellent foundryman, and understood perfectly every detail of foundry practice, but he had permitted his mind to become centered upon turning out perfect castings, and must have a perfect rig to do it with, and by so doing lost two excellent positions at a good salary.

A foreman should always remember that he is employed to make money for his employer, and his wages will be in proportion to his ability to do so, and if he permits himself to indulge in special rigs, new flasks, high-priced moulders, etc., to an extent that there is no profit on the castings turned out, his employer will have no use for him, no matter how perfect his castings may be.

Superintendent of Foundries.

The position of superintendent of foundries is one that has been created in the past few years by firms or companies having a number of foundries located in different sections of the country, with a view of placing them all under one management, and obtaining more uniform results in their foundry plants. This plan has proven satisfactory to some firms and been abandoned by others after a trial.

This is a very delicate position for a man to hold, for, as a rule, foremen object to being interfered with or dictated to by any one, and more especially by an outside man who is employed for that purpose. He must be handled with care or the superintendent will soon find things going worse in the foundry and himself in a peck of trouble.

A man for this position must be a thoroughly practical, up-to-date foundryman, capable of locating the cause of all troubles that may occur and give a remedy for them. He must act in an advisory rather than a dictatory manner. For if he gives orders for what is to be done he must assume responsibility for results, and if he gets the ill will of the foreman he may throw up his job at once or make him an endless amount of trouble, as may also the moulders, who would naturally side with the foreman.

The best method for such a superintendent to pursue, for his own good and the good of his employer, is to act in an advisory manner by suggesting how any trouble that may arise can be overcome and leaving it to the discretion of the foreman to carry out his suggestions or not, as he thinks best. If his suggestions do not give the results desired, and there is reason to believe that they have not been followed out, then the only thing for the superintendent to do is to discharge the foreman or take charge himself and endeavor to locate the trouble and overcome it. In doing this he may find it necessary to discharge the foreman and the entire force of moulders. It may even be necessary to call down some of the office force in the matter of furnishing supplies that are not what they should be.

This makes the position of superintendent of foundries one that can only be filled by a very competent man if the quality of castings is to be improved or the output increased. But if there are other objects in view in the employment of such a man, any figurehead with ability or in a position to accomplish the object in view, will answer the purpose.

Handling of Workmen.

A knowledge of men and of the handling of men are qualifications absolutely necessary in a successful foreman.

For him to put a light, delicate man at work handling pig-iron would be absurd, for he should see at a glance that the man had not the muscular power requisite for such work. To put a heavy, muscular man at work on a light job, requiring quick motion and activity, would be equally absurd. These and other qualities can be judged by the eye, and no talk is necessary.

To put a bench moulder at work to mould a large cylinder with complicated cores, would be absurd, and to put a heavy cylinder moulder to work at bench moulding would be equally absurd, for both men would probably prove a failure. The first due to lack of knowledge in such moulding and the latter due to lack of interest in his work.

Men work better when they have work to their liking, and a foreman should always endeavor to give his moulders the kind of moulding they like, or have been accustomed to. Before employing a moulder he should be questioned as to the kind of work he has been moulding; the length of time he has been moulding, etc. For in these days of machine moulding, and especially foundries, there are but few all-around moulders capable of moulding any piece, and to put a moulder to work when there is no job to suit him is only subjecting his employer to loss.

The handling of workmen is another important factor which the successful foreman must possess or acquire, for it makes no difference how much more he may know about founding than his workmen, if he cannot impart this knowledge to them for their benefit and the benefit of his employer, and by so doing insure a fair day's work and good castings, then his superior knowledge is of no value to his employer and he will prove a failure as a foreman.

He should be patient with all men placed under his charge, and always remember that these men are not supposed to know

as much or more than he does, for if they did they would be foremen and he workman. He should treat them with the same respect and consideration that he would expect or desire from them if any one of them were foreman.

The yelling and swearing at workmen by a foreman is humiliating to a good man, whether moulder or laborer, and he generally takes the first opportunity to get away from this kind of treatment by accepting another job. A foreman will soon find himself with a shop full of inferior workmen who pay no attention to his yelling and swearing and do as they please as soon as he is out of sight, with the result that castings cost more than they should, and the foreman is a failure.

A foreman should never reprimand a workman in the presence of other workmen, or threaten to discharge him, for this creates a spirit of getting even with the foreman and this the men may do in the foundry or outside by talking to other workmen and make the foreman any amount of trouble.

In case a man's work or conduct is not satisfactory he should be spoken to quietly at his work, or called to the office and his attention called to any matters that are not satisfactory. If this does not improve matters, he should be talked to again, and if this does not give satisfactory results it indicates that the man is not competent to do the work, or is lazy and indolent. In which case he should at once be given work that he can do, or be discharged.

When a new man takes charge of a foundry that has been in operation for many years he may find a number of old men at work who do not earn the wages that are paid them; these men have no doubt been good workmen in their younger days and employed in the foundry for many years, and in the early struggle of the founder of the plant, rendered valuable service in making the plant a success, and are kept at work and are given the wages they are receiving for this past service, rather than for the work they are doing. Such men must be handled with care by a new foreman, and before urging them to do more work, reducing their pay or discharging them the proprietor or manager should be consulted in reference to them. If old employees, they should be permitted to do about as they please, if not otherwise ordered. For, in many cases, to offend one of these men is to offend the management and often many of the workmen.

A foreman should have full authority over all men placed under his charge, with full power to select, hire and discharge them, for it is only by such authority that he can control them,

and all orders to workmen should be given to the foreman and not to the man. For a man with two bosses has no boss at all.

Producing in a Foundry.

The moulders employed in a foundry are the only producers, for they are the only men that make castings and castings are the only salable product of a foundry. All other men employed in a foundry, such as helpers, laborers, cupola men, core makers, foremen, flask makers, crane men, etc., are only helpers to the moulder, for they produce nothing that is salable. Another set of men who may be classed as outside men, such as manager, draftsmen, pattern makers, clerks, book-keepers, engineers, teamsters, etc., are helpers to the moulders to the extent that their time is charged to the foundry, for they, like all men employed in or in connection with a foundry, must receive their pay from the profits on castings turned out by the moulders, and if these profits are not sufficient to meet the pay roll and leave a profit for the founder, then the foundry is a failure.

It will therefore readily be seen that in order to make a foundry pay the help must be in proportion to the number of moulders employed and each moulder must do a fair day's work for his day's pay.

The reason why many foundries do not pay is that they are so poorly designed, that the flask yard and carpenter shop are too far away from the foundry. Castings have to be carried back and forward to the cleaning room and finishing room. The distance for wheeling iron and coke to the cupola and removal of dump is too long, and extra help is necessary.

Another reason is that men are permitted by incompetent management to loaf on the job, and extra men are necessary to get the work done. This is the case with many foundries run in connection with machine shops and other plants, and if separated from them could not earn their pay roll on the output of castings.

The labor problem is a very important matter in foundry practice and every device to save labor should be put in to make it a paying proposition.

Management and Office Force.

Another matter that should be carefully looked after in making a foundry pay is the management and office force. This in many foundries is made an expensive luxury by the fitting up

of expensive offices and the employment of unnecessary managers and an elaborate book and cost keeping system, requiring many book-keepers, clerks and office boys, all of whom are non-producers.

I have frequently been called upon to determine why a foundry plant did not pay, and to make suggestions for putting it on a paying basis. At one of these foundries in the South I found twelve colored moulders at work, moulding pipe fittings on stripping plate machines. Not one of these men had served an apprenticeship at moulding and only three of them were putting up a full day's work. In the office force I found seven men; these were the manager, treasurer, superintendent, four book-keepers or clerks. The manager's and treasurer's salaries were five thousand dollars each; the superintendent, three thousand dollars, and the four office men's salaries averaged three dollars per day each. Which, for three hundred working days during the year, amounted to three thousand six hundred dollars, or a total of sixteen thousand six hundred dollars per year for management and office force. This amount when divided by twelve gives four dollars and sixty-one cents as the management and office cost for each moulder per day. Adding this to the moulders' wages and the wages of a foundry foreman, core room foreman, core makers, cupola men, laborers, etc., the labor cost per moulder was over ten dollars per day for each moulder. There was not this amount of profit on the castings turned out by any moulder in the foundry, and of course the foundry was running at a loss.

I pointed out this condition of affairs to the manager and suggested that his salary and that of the treasurer and superintendent be reduced and the office force be reduced to one man. But the manager and treasurer were the promoters of the plant, the superintendent and office men were stockholders, and this could not be done. I then suggested that the service of the core room foreman be dispensed with, a more competent foundry foreman be secured, and the moulders be given instruction in moulding and the output of castings increased. This was attempted, but before it could be reduced to a practical basis the reputed millionaire lumber man, who had been furnishing the money to keep the plant running, got tired of his job, and the plant closed down and remained closed until it was reorganized on a practical basis, with competent men in charge, and it was then made a success.

A plant in New York State which I investigated had a manager, superintendent, assistant superintendent and foreman. An

office force of eight men and women, and about twenty moulders. This plant did not make sufficient money to pay the office force, and after running at a loss for some time, the principal owner took charge of it, discharged the entire management and office force, discontinued the red tape system always connected with such a management, and made the plant a success.

The cost for non-productive labor in the management, office force and foundry is a matter that must be very carefully looked after in making a foundry pay, for if its cost is in excess of the profits on the castings turned out by the moulders the foundry cannot be made a paying investment. There are two ways of solving this problem. One is to reduce the cost of non-productive labor, the other to devise means of increasing the output of castings.

Some years ago there were two foundries in Philadelphia, each of which had a capacity of about twenty moulders. One of these foundries was run by a New England foundry man and was known as a Yankee Foundry. The other was run by a German. Each of these men managed his business and employed only a shipping clerk and foreman to assist him in management. The Yankee foundry had a slate upon which a record was made of the delivery of castings, orders received, etc., and when time permitted during the day, or in the evening, entries were made in the books from the slate.

One day the German's clerk informed him that he wanted a new account book and some paper. The German said: "You don't need any book and paper; look at the Yankee Foundry, they keep all their books on a slate."

The Yankee Foundry man made a fortune and retired. The German founder was successful, and his sons now have one of the best managed and most successful foundries in Philadelphia.

Efficiency in Hiring and Discharging Workmen.

Cost of hiring and discharging workmen is presumed by every manager to be expensive, but very few have given publicity to the detailed expenses; indeed, it is somewhat doubtful if this most important factor in industrial methods of management has ever received the close attention it deserves.

However, M. W. Alexander, of the General Electric Co.'s plant at Lynn, Mass., has recently presented some surprising figures. They show an economic loss by indiscriminate hiring

and the essential training of workmen that has not generally been recognized.

An employer increasing his force from 1000 to 1200 in a year would need to contemplate the employment of only 200 additional men if conditions were ideal, but some workmen die, or become ill for long periods and must, therefore, be replaced, while others prove unfit for the work. Just how many times the original recruiting force must be multiplied has been a matter of the wildest speculation rather than close commercial calculation before Mr. Alexander's figures were at hand.

A group of factories was selected by Mr. Alexander for investigation, the total number of workmen of various grades employed being about 42,000. From January 1 to December 31 the number of men at work increased to 48,697, an actual increase in the permanent force of 6,697 men. To gain this increase 42,571 men were actually hired and set to work.

It is thus seen that at the end of one year only about 16 per cent. of the men employed were retained. The investigator concluded that hiring 22,200 of these men could have been avoided, this number being reached by assuming that 1 per cent of the employees die, that 5 per cent leave on account of sickness, that 10 per cent either withdraw or are discharged, and that the efficiency of the employment department is 75 per cent.

The economic loss from indiscriminate hiring and discharging of workmen was classified by Mr. Alexander under the following heads:

- a. The clerical work of hiring.
- b. The instruction of new employees by the foremen and assistants.
- c. Increased wear and tear of and damage to machinery and tools by new men.
- d. Decreased rate of production during the early period of productivity of the new men.
- e. Increased amount of spoiled work by the new employees.

Using above classification and percentages to analyze the direct loss to the employer, and by dividing the workmen into various classes, Mr. Alexander found that the 22,200 men who should never have been employed caused an actual loss of over \$35 per man, or a total of about \$777,000 in one year. To decrease this loss the following suggestions are offered:

a. A careful study of current employment statistics should be made with an analysis of the reasons for the discharges.

b. We need a far higher grade of men in charge of the hiring and firing of men than we have had heretofore in our employment clerks.

c. While it is important to exercise proper care, thought and study in the hiring of employees, it seems vastly more important to apply the proper methods in initiating new employees in the work, and to treat them properly.

d. We ought to have effective systems of apprenticeship, factory schools, special training courses, or whatever name you may call them, so that we may not be dependent only on the grown-up men as they float around the country, but that we may effectively take hold of the youths of the country and train them in the ways of our industry, and in loyalty and intelligence.

e. So far as it can be done, we ought to be able to regulate a little more the commercial requirements as they come to the factory.

Investigation of several factories in England and Germany indicates that the conditions existing in these countries are similar to those found in the United States, proving that the problem is international.

Boys As Expensive Operators of Cranes.

An instance where the price of inexperience may be fixed at high level by law following an accident.

Company employing many foreigners in foundry followed local custom of having boys for crane operators. It was desired to move a heavy casting from the corner where it was piled out of the way. A chain hitch was made around the pouring gate which was still attached to the casting. Word was given to hoist away. Boy ran his trolley away from above the load and then threw over his hoisting switch. The sudden strain broke away the casting gate and swung it toward the main floor. On the way it hit and seriously injured a moulder.

Now the company is defendant in a \$25,000 damage suit—but grown men are used for crane operators, and all hoisting work is done in vertical lifts.

Efficiency

CHAPTER XII.

Efficiency.

Probably in no other industry is there a greater opportunity to improve conditions and increase profit by efficiency than in the foundry industry. Efficiency means the elimination of waste and loss by a correct system or method of doing things.

In many foundries there is no care taken of stock whatever. Moulding and core sands are piled in the yard to be washed by the rain, trampled into the mud in wet weather and tons of it lost. Coke is piled in the same way, and crushed by wagons driving over the edge of the pile and trampled into the mud. There is also a loss of these materials through carelessness by loading barrows in such a way that pieces of coke fall off and are not picked up, and the runway from the coke pile or bin to the cupola is lined with coke. A trail of sand is left from every barrow from the sand pile or bin to the moulding floor or core room.

Pig iron is thrown from cars or wagons upon soft ground, sinks into the ground, and if the piece of ground so used is dug up, after iron has been so piled for a number of years, or even a shorter time, the founder will be surprised to find the member of pigs that have sunk out of sight and never been missed.

Scrap iron disappears in the same way, and when broken upon the ground very small pieces are seldom picked up, and tons of scrap are lost in this way. This loss of pig and scrap may be prevented by providing bins for both pig and scrap. These may be constructed very cheaply of old railroad ties set

on end in the ground, and for pig iron a floor may be made of the same material. A scrap bin should have a concrete floor and small pieces recovered each day to prevent them being destroyed by rust.

The handling of this material is another thing that should be carefully looked after. Barrows are overloaded or broken by throwing pigs upon them and frequently break down and they and their load are thrown to one side and left there. Scrap falls from barrows and is not picked up, and many foundry yards are so littered up by such carelessness and neglect as to be dangerous to life and limb.

In many foundries there is no system to their cupola practice. Nothing is weighed that goes into the cupola, the weight of coke, pig and scrap is guessed at, and there is an extravagant use of fuel, heavy destruction of lining, with a heavy loss of casting due to poorly melted iron.

But the greatest inefficiency is in the moulding department. There have been but few regular apprentices at moulding for years who served their full time and become good, all around moulders. The places of moulders have been filled by moulding machines and handy men. These men are not properly instructed in either machine or floor moulding, and are expected to learn moulding from observing the working of men who have not been properly instructed in the art of machine or hand moulding.

A proper instruction of machine moulders in the handling of the machines would greatly reduce the cost for repairs and give greater efficiency, and a proper instruction of floor and bench moulders in the elimination of waste and motion, proper handling and placing of tools, patterns, flasks, boards, etc., convenient for use would in many cases greatly increase the output of castings.

There are but few large foundry plants that could not greatly increase their profit by the employment of an efficiency man, whose duties were to look after the matters enumerated and many more in which a saving could be effected by proper care.

Such a man should be a thorough, practical moulder, capable of giving proper instructions to not only new beginners, but also

to regular moulders, many of whom have not been properly instructed and are as inefficient as new beginners.

Whistle Telephone Call.

Large plants with telephone connections with the main office to the various departments can obtain more prompt and efficient service by placing a small steam or compressed air whistle in a central part of the plant, where it can be heard all over the plant, and have a whistled code by which a certain number of toots of the whistle calls to the phone the head of the department wanted.

The phone call is made to the foreman's office, and if there is no answer the whistle is tooted. This lets him know that he is wanted on the phone, and he at once goes to it. This saves a great deal of time in having a runner or office boy hunt him all over the plant and greatly increases efficiency.

Cost Keeping.

A great deal has been said and written about cost finding and cost keeping systems in foundry practice, and many of these systems have been published in the foundry and other periodicals. Most of the systems so published have been prepared by accountants not familiar with the details of foundry practice, and while they show up very nicely in print are entirely too elaborate and expensive for a foundry plant. The added cost for books, paper, printing and non-productive labor for collecting the data and preparing the report is so large that the cost is greater than the saving effected by the cost-keeping system. Also cost of production is increased rather than decreased by the system.

The various cost-keeping systems as published appear to be all based upon two plans. These are the co-operative system and the record system.

By the co-operative system the workmen are required to co-operate with the management to the extent of furnishing the data from which to make up the estimate of cost of production.

I had an opportunity of observing the working out of this system in a large Philadelphia foundry plant a few years ago. This system was a very elaborate one, designed to cover every possible cost and be inexpensive in collecting the data. Daily work cards were issued to each workman, upon which they were required to make a detailed record of the time spent in moulding each casting, cleaning the casting, chipping it, making cores, etc.

This system was at once denounced by the workmen as a spy upon them, and every one of them, from the foreman down, at once started to make it a failure. The cards were filled out in such a jumbled up way that the desired information could not be obtained from them. One common complaint made by the workmen was that they had no watch and could not state time, and clocks had to be installed all over the plant. This did not improve matters, and the foreman was appealed to to fill out the card. But he, being in sympathy with the men, stated that he had no time to make out cards without neglecting his other duties as foreman.

A young man who was not familiar with the details of foundry work was then sent out from the office to fill out the cards. The men easily managed to give this man the details of their day's work in a way that it was of no value in cost keeping. A moulder would give a minimum time for moulding each piece and account for the balance of his time in waiting for the crane, patterns, flasks, hunting clamps, jagers, etc. A coremaker would account for his time in waiting for sand, binder, core boxes, etc. And complaints of this kind were so numerous that a servant would have been required for almost every man in the plant.

The collection of data in this way, although not at all reliable, was continued, and three men were employed in collecting, classifying, figuring out daily costs and placing it in books for reference. The salaries of these three men, together with cost for cards, paper, printing, books, etc., amounted to about \$2500 per year, and increased the cost of castings to that extent.

This firm, although it had plenty of work and did a large business for years, melting as high as fifty tons of iron per day, finally went out of business without ever having declared a dividend during their existence, which would indicate that their cost-keeping system was not a success.

This same system has proven a complete failure in a number of foundries I have visited and been abandoned by them.

The record system of cost keeping consists of a set of blanks to be filled out by the head of the various departments, and is entirely independent of the workmen. The following set of blanks for this system were furnished by a large foundry company who have had this system in use for a number of years and report it very satisfactory.

The casting order we show is a card that is filled out at the main office on receipt of order for every casting to be made and

LOT NO.	NO. PCS.	NAME OF PIECE	MAT.	PATTERN NUMBER

CASTING ORDER B 2861

TO

AV. WT.

DATE OF ORDER	PCS. WANTED PER DAY	START DELIVERY	DELIV'Y MUST BE COMP.

REMARKS				SHIPMENTS			
				DATE	NUMBER	BALANCE	DATE

FOUNDRY OFFICE COPY

sent to the foundry office. The following is an explanation of this card: Lot No. is the number of order to which the casting belonged and is to enable the cleaning department to pile or place each casting in the lot to which it belongs and save time and labor in hunting for castings. No. Pcs. is the number of castings to be made and cleaned. Name of piece is for cleaning and shipping. Mat., the metal in which it is to be cast—hard, soft or close iron, brass or other metal. Pattern No., number of pattern, all patterns being numbered. The name of party ordering and their pattern number inserted. Casting order B 2861 means the number of this particular order for filing purposes. Av. Wt., weight of casting, is a guide for cleaning and shipping. Shipments form is for recording shipments of order in parts. When the order is completed the card is returned to the office with its detail all filled out.

Three of these forms are printed on different colored paper, marked Pattern Copy, Casting Department Copy, Moulding Department Copy. On receipt of the order the foundry clerk fills out one of these blanks for each department. That for the pattern foreman gives name of customer and their pattern number or shop number, if they do not furnish their own pattern, and name of piece. He at once finds the pattern, sees that it is in good condition and has it ready when called for, and there is no waiting for the pattern by the pattern carrier or moulder. When the pattern is delivered the card is placed on file, and when the order is filled he sees that the pattern is returned to its place.

That for the moulder is filled out and sent to him, with the pattern, so that he knows the total number and just how many is wanted per day, and is informed of the number of defective castings found in cleaning, to be made up, and when the order is completed returns the card to the office, with the record of the number of perfect castings made.

That for the cleaning department is filled out and sent to this department, and serves as a guide for cleaning, sorting, piling and reporting defective castings.

The four cards all bear the same number and when the order is completed are returned to the main office and give all the information necessary for cost estimate of labor in producing them.

Foundry Daily Scrap Report. This is filled out by the head of the casting cleaning department and shows the number of castings lost each day and cause of loss. This report enables

the foreman to call attention to the moulders, of their loss and cause of loss that it may be avoided and also gives the main office information as to what is being done in the foundry.

Foundry Time Ticket. This is a card to be filled out by each moulder and shows the number and kind of castings made by him daily or weekly. The item No. in flask refers to number of patterns moulded in each flask. This is a check-off on the practice of some moulders of putting up a large number of flasks with very little in them to make a showing of a big day's work on the floor, save time and labor in finishing the mould and have little iron to carry.

Daily Report of Castings. This is the cupola report. This is filled out by the foreman for the cupola man to charge by and after the heat the other items are filled in.

The weekly report is filled out from the other reports by the foundry clerk.

These cards or reports when correctly filled out and returned to the cost-keeping clerk give the production and its cost for labor, etc., that properly belongs to the foundry and is a check-up on all delinquents but does not cover cost of material and foundry supplies or overhead charges. These are obtained from the office books and stock on hand.

This is about the most perfect cost-keeping system, so far as the foundry is concerned, that I have seen in use, for it obtains all the data necessary for cost estimating and the work of collecting data is so divided up that it costs practically nothing for obtaining it.

Weight of Iron.

Carbon in iron decreases the weight of iron by increasing its bulk. The form the carbon assumes in iron also has a marked effect in increasing bulk and decreasing weight in iron of the same bulk.

A cubic foot of pure iron weighs 489 lbs. One of white cast iron with the carbon all in combination with the iron weighs 474 lbs.; one of mottled iron weighs 458 lbs.; one of grey iron weighs 450 lbs., and one of dark grey or No. 1 foundry iron, with the carbon nearly all in the graphite state, weighs 425 lbs., making the difference in the weight of a cubic foot of pure iron and a cubic foot of No. 1 foundry iron 64 lbs. The difference between a white iron that may be cast and a No. 1 foundry soft

iron is 49 lbs. A casting cast from the same pattern, of white iron and one cast of grey iron, differs to that extent in weight. A casting weighing a ton in grey iron, weighs approximately 230 lbs. more when cast in white iron. This is a matter that must be taken into consideration when figuring the weight of a casting from measurement and in estimating the weight of iron required when making up a heat.

The weight of one cubic inch of these irons in ounces is as follows: White iron, 3.65; mottled, 3.77; grey, 3.84; No. 1 foundry, 4.07. Multiplying these weights by the cubic inches in a pattern gives the weight in ounces, and dividing the number of ounces by 16 gives the number of pounds of iron in a casting of any given measurement.

But in castings a pattern is liable to swell and cores are liable to shrink in drying and an allowance must be made for this, and also for gates, risers, sink heads, etc., and it is always better to have a little iron over than a little iron short, and a liberal allowance over the weight indicated should always be provided.

In making up a heat it is the practice to estimate each cubic inch as four ounces for grey iron, and dividing the number of cubic inches in a pattern by four gives the number of pounds the casting will weigh.

Price List of Analysis.

The following are the prices for analyses of metal and other materials of one of the leading laboratories of Philadelphia, Pa.:

Iron and Steel.

Silicon	\$0.75
Sulphur (iodine method).....	.75
Phosphorus	1.00
Manganese	1.00
Graphite	1.00
Total Carbon	1.50
Sulphur (aqua regia method).....	3.00
Sil. Sulp. Phos.....	2.25
Sil. Sulp. Phos. Mang.....	3.25
Graphite. Total Carbon {	
Sil. Sulp. Phos. Mang. {	5.50

DAILY REPORT OF CAST

DATE					WEATHER							
NO. OF CHARGE	FLUX	COKE	RETURN	SCRAP	DIFFERENT BRANDS OF PIG IRON						TOTAL IRON IN EACH CHARGE IN POUNDS	
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
TOTALS												

ONE POUND COKE MELTED	CONDITION OF IRON	COLD	GOOD	HOT
MELT PER HOUR	BLAST PRESSURE IN OZ.			
GOOD CASTINGS	BLAST PUT ON			P. M.
BAD CASTINGS	BOTTOM DROPPED			"
RETURNS	TIME	HOURS		MIN.
FROM WATER MILL	PIO IRON WAS		% OF CHARGE	
SHORTAGE	SCRAP AND RETURNS WERE		" "	
FROM MOULDERS	GOOD CASTINGS WERE		" "	
FROM MLCG. MACHINES	BAD CASTINGS WERE		" "	
NO. FLOORS	RETURNS WERE		" "	
TOTAL NO. OF MEN	SHORTAGE WAS		" "	

REMARKS

Size 8 1/2 x 11 inches

Ferro Alloys and Special Steels.

Silicon	2.50
Sulphur gravimetric	3.00
Phosphorus	2.00
Manganese	2.00
Carbon	2.00
Nickel	3.00
Chromium	2.50
Tungsten	2.50
Vanadium	5.00

A reduction will be made when three or more elements are determined in one sample.

Coal and Coke.

Moisture, Vol. Combustible; Fixed Carbon, Ash, Sulphur and Phos.....	8.00
Moisture, Vol. Combustible; Fixed Carbon, Ash.	3.00
Ash and Sulphur.....	2.50
Sulphur	1.75
Phosphorus	3.50
British Thermal Units.....	5.00

Limestone, Sands, Clay, Cement

Silica, Oxide of Iron, Alumina, Lime, Magnesia, and Loss on Ignition.....	10.00
Sulphur Trioxide (in cement).....	1.50
Specific Gravity	1.00

Iron Ore, Mill Scale, Puddle Cinders, Etc.

Silica	2.00
Iron	2.00
Phosphorus	3.00
Manganese	2.50
Sulphur	3.00
Moisture	1.00

A reduction will be made where three or more elements are determined in one sample.

Brass, Bronze and Babbitt Metals.

Aluminum, Antimony, Copper, Lead, Phosphorus, Tin, Zinc, each..... 3.00

A reduction will be made where two or more elements are determined in one sample of these alloys.

Remarks: A small charge will be made to cover cost of any drilling required on samples of iron, steel or alloys.

The above were the prices just before the war, they are much higher just now, but these prices will probably be restored when the war is over.

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